IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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EDITORIALS

OUR 1928 CONVENTION

On Saturday, June 18th, 1927, a dinner was tendered to a representative group of exhibitors at the Iron and Steel Exposition. One representative from each company was requested to be present at the meeting with the idea of offering whatever suggestions and criticisms they had in mind for the betterment of future affairs of this nature. Much good was accomplished from the discussion which followed and everyone agreed that it was the biggest and best affair in the history of our Society.

Coming to the point of suggesting the city for next year's convention, it was the unanimous opinion of all those present that we should endeavor, if at all possible, to select the City of Chicago for 1928.

Your Board of Directors are now pleased to announce that the City of Chicago has been selected and the Hotel Stevens in Chicago as the official convention and exposition headquarters.

With their spacious Exposition Hall equipped with all the services necessary for the proper display of equipment, such as it is our pleasure to inspect, and with reasonable rates in force, this hotel was given preference over other locations.

Floor plans and other details connected with the exposition and convention will be placed in the mails November 1st and this should give ample time for the selection of space and preparation of exhibits for the exposition.

It is our wish that during the convention week of June 25th to 30th, 1928, our Association will be enjoying its most successful convention and exposition. Help to make it so.

OUR PHILADELPHIA SECTION

On the opposite page is pictured part of the group of engineers who, on May 6th of this year, spent an interesting day at the Edison Lighting Institute, Harrison, New Jersey.

After the luncheon, the engineers were welcomed to the Institute by Mr. L. W. Teegarden and the program for the afternoon commenced. Talks on various phases of lighting were given by several of the Lamp Works engineers.

The principal address of the afternoon was given by Mr. A. B. Oday on the subject of "Industrial Lighting." During the course of his talk, he showed how production increases averaging 15% had been obtained in many factories by the installation of improved lighting. He spoke on the important relation existing between light and safety and showed by means of charts how many common industrial accidents could be avoided.

Various type of lighting equipment were displayed and their proper uses discussed.

In the informal discussion which followed the address, various lighting problems were brought up and dealt with by Mr. Oday.

The visiting engineers were conducted through the Institute where many historical objects, equipment and lighting effects were viewed.

The members of our Philadelphia Section feel highly honored in being afforded the opportunity of hearing such excellent papers and witnessing the latest developments in the lighting art.

In concluding the meeting, a rising vote of thanks was extended the Edison Lighting Institute for their many kindnesses.

1927-1928 SEASON

Each year the months of July and August find the roads to various pleasure resorts well lined with those who are on their way to a well earned rest from the daily routine of their "jobs." Within a few weeks, most everyone will have spent their summer vacations and will again be back at work on the tasks confronted in their every day work.

The Birmingham, Chicago, Cleveland, Philadelphia and Pittsburgh Sections of your Association have refrained from holding any affairs during these months for the reason that it was their desire to have as many members and guests as possible participate in their 1927-1928 programs.

Your District Officers and Committeemen have been elected for the coming year and are working towards making their year the banner one in the history of the Society.

Picnics, Golf Tournaments, etc., are on the program for the first month with Inspection Trips, Technical Sessions and social affairs to follow.

With the stored up energy now at your disposal, why not make it a point to lend your assistance to those of your section who have been and still are devoting much of their time so that you, your company, and your section might enjoy those benefits which it is your privilege to have with but little effort on your part.

THE AUGUST ISSUE

This issue contains papers of particular interest to all engineers who have charge of large generating or converting power units. There are also discussions on electric heat and bearings. In addition, we have obtained a paper on Centrifugal Compressors that will be extremely interesting to all mechanical and electrical men.

The paper by Ernest Pragst on "Parallel Operation of D. C. Generators and of D. C. Generators with Synchronous Converters," deals with a subject which is of paramount importance to large users of direct current power. Undoubtedly, circulating current losses may be reduced and more satisfactory parallel operation obtained by application of the principles contained in the paper by Mr. Pragst.

Mr. W. B. Shirk has furnished a paper entitled "Parallel Operation of Synchronous Converters for steel mill applications," which supplements the paper by Mr. Pragst. We all realize that Synchronous Converters can cause a great deal of trouble unless properly handled and Mr. Shirk's paper should, there-

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The Parallel Operation of Mercury-Arc Rectifiers: With Each Other, With Rotary Converters and With Motor Generators*

By O. K. MARTI†

THE parallel operation of mercury-arc rectifiers with each other, with rotary converters, and with motor generators, can be understood by reviewing the theory of the performance of rotary converters under these conditions. There is, for instance, the same arrangement as to transforming the primary power according to the desired d-c. voltage, and at the same time splitting it into a larger number of phases in the secondary. The only difference is that in the case of a rotary-converter set the voltage regulation is due to the variable voltage drop in the transformer and in the rotary converter itself as well, while in the case of a rectifier the voltage drop in the rectifier proper is practically independent of the load, and we have therefore only to consider the voltage regulation of the transformer. Furthermore, another characteristic difference is in the fact that a rectifier can furnish power only from a-c. to d-c. Both of these interesting characteristics have to be considered when the question of parallel operation of rectifiers is studied.

Before going into the details of this problem, it would be well to review briefly the fundamentals of

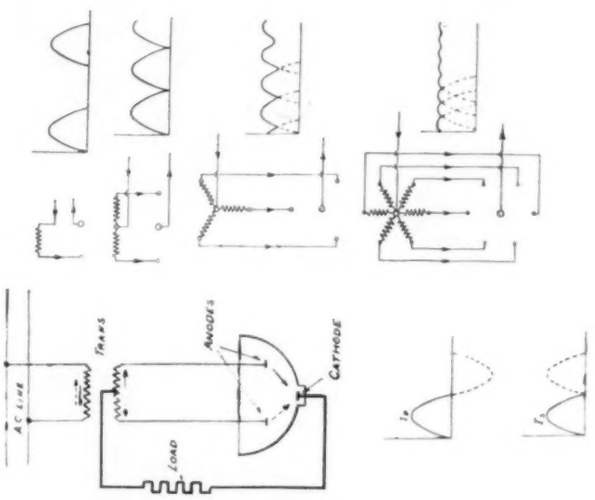

FIG. 1—Elementary Diagram of Single-Phase and Polyphase Rectification.

the rectification of alternating current by means of a steel-enclosed mercury-arc rectifier. This apparatus does not first change the electrical energy into mechanicag energy, and then convert the mechanical back into electrical energy again, but it transforms the electrical energy directly, without any rotating parts, and is in that way similar to the static a-c. transformer used for the transformation of alternating current of one voltage into alternating current of another voltage. The action of the mercury-arc rectifier depends on the fact that under certain conditions current can flow in only one direction between two electrodes in a vacuum. The conditions are met in the case of the rectifier by using a mercury and a steel electrode (See Figs. 1 and 2.). From Fig. 1 it is evident why it is better to use several phases on the a-c. side instead of only one phase; both halves of the cycle are utilized; an arc is continuously maintained; and the direct current produced is less uneven. However, even with single-phase operation using two anodes, an arc would continuously be maintained in the rectifier, due to the inherent inertia of reactance which is characteristic of every electric circuit. This would maintain the arcs between both anodes and the cathode for a short time, thus preventing the arc from being extinguished. Theoretically, therefore, the greater the number of anodes the smoother the rectification, but for practical considerations six and twelve anodes are the usual number used in such apparatus.

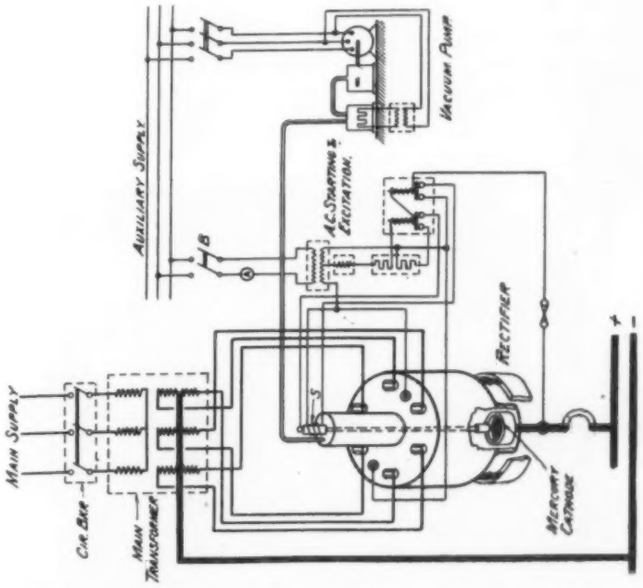

FIG. 2—Schematic Layout of a Mercury-Arc Rectifier Installation.

In actual installations, furthermore, an auxiliary supply is needed for starting the rectifier and for maintaining the arc during periods when there is little or no load on the d-c. side. This auxiliary supply also drives the vacuum pump, which automatically maintains a high degree of vacuum in the rectifier cylinder.

As can be seen from Fig. 2, the arc is struck when the solenoid S is energized by the starting and

*Presented at Philadelphia Section, March 5th, 1927.

†American Brown Boveri Electric Corporation, Camden, N. J.

excitation transformer. This solenoid is energized as soon as the switch B is closed, and it lifts the plunger to which it is connected out of the mercury cathode, causing a momentary arc. The ionization of the mercury vapor which is produced by this arc is sufficient to start an arc between the main anodes and the cathode, the whole operation consuming only a very few seconds. A set of smaller anodes, also connected to the starting and excitation transformer, serve to maintain a sufficient degree of ionization of the mercury vapor in the tank when there is very little load on the d-c. side, as explained above. They are also indicated on Fig. 2. These take only a very

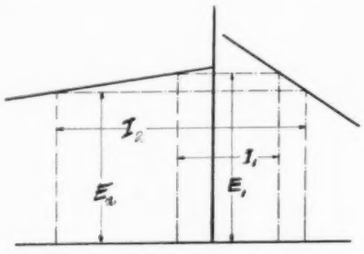

FIG. 3.

little current, as it takes hardly any power to maintain the exciting arc in a stable condition.

A fact of particular value in the operation of the mercury-arc rectifier is that the voltage drop in the arc itself is merely the same at all loads and at all voltages. Consequently, the losses in the rectifier proper remain practically constant with increasing voltages; therefore, since the voltage drop in the arc is approximately 20 volts, the efficiency of a rectifier delivering d-c. at 20 volts would be but 50%, while at 200 volts the efficiency would be 90%, and at 2000 volts and above it would lie somewhere between

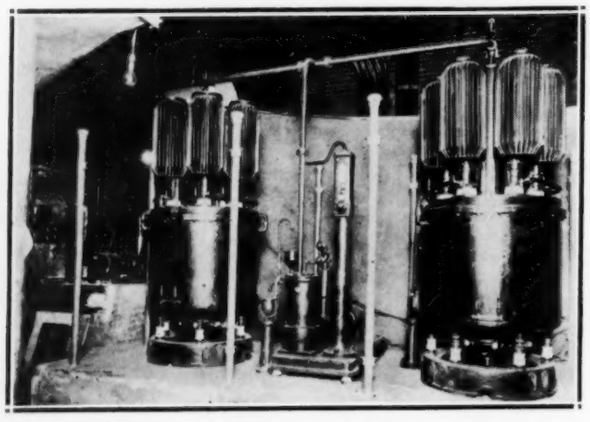

FIG. 4—Rectifiers in Gold Street Substation of New York Edison Company.

99% and 100%. Of course, the efficiency of the whole plant is slightly lower, on account of the losses in the transformer and auxiliary equipment. These last-mentioned losses are also primarily the reason for the difference in the efficiency of a rectifier at partial load, full load, and overload. However, even so, these differences are smaller in a rectifier plant than in an installation using rotary converters, and much smaller than with motor-generator sets.

To parallel one mercury-arc rectifier with another or with a rotary converter, all that is necessary is the ordinary starting operation of closing the main circuit breaker and the auxiliary switch B (both usually being done simultaneously), and a few seconds later the d-c. line can be supplied with power. No synchronizing is necessary, the polarity of the d-c. terminals does not have to be checked (and possibly reversed by several renewed starting operations), and no power can feed back from the d-c. side to the a-c. side should any part of the installation be improperly adjusted or fail to function correctly. In case the voltage regulation of the main transformer of the rectifiers is similar to that of the converter which is already supplying power to the d-c. bus, successful parallel operation, i. e., a proper division of the load, will automatically take place; the same fundamental conditions enter into the parallel operation in this case as do in the case of rotary converters or motor generators.

As can be seen from the foregoing, the voltage regulation of the rectifier is entirely a function of the design of the transformer, and by means of special arrangements, such as absorption-reactance coils or the use of a saturated-core inter-phase transformer,

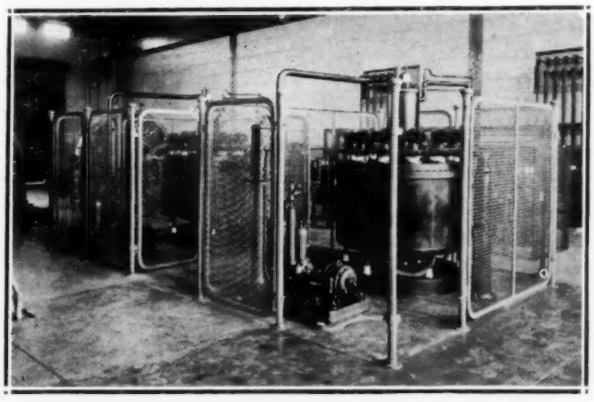

FIG. 5—Rectifiers in Harvey Substation of Commonwealth Edison Company, Chicago.

practically any voltage regulation can be obtained. The standard type of Brown Boveri rectifier has a voltage regulation, depending upon transformer design and arrangements of connections alone, of 5 to 10 per cent from no-load to full load. Closer regulation can be obtained by means of the above-mentioned auxiliary arrangements, should it be desired. Such auxiliary arrangements, especially the ones giving over-compounding, were very seldom used in Europe, because it was always easily possible to secure satisfactory parallel operation by adjusting the voltage characteristic of the already existing machines, and thus to meet the rectifier characteristic half way.

It is sometimes desirable to connect two rectifier cylinders to one transformer. In such a case special considerations have to be taken into account in the design of the transformer so as to effect a proper division of the load between the two rectifiers.

Sometimes it is very desirable to improve the overall efficiency of an old converting station which has a very low load factor. In case the station is equipped with synchronous converters or motor generators a very remarkable improvement can be ob-

tained by having a rectifier working in parallel with the old machines.

The efficiencies of the two latter types of converters are lower at overloads and at partial loads than the efficiency of the rectifier. In order to obtain, therefore, a good annual average efficiency for the plant, it is desirable to design these two types of converting devices for such load characteristics that in parallel operation the rotary converter or motor generator is always working at practically full load, while the fluctuating peaks are taken care of by the mercury-arc rectifiers. Assuming that the load characteristic of the motor generator is shown on the right-hand side of Fig. 3, and the load characteristic of the mercury-arc rectifier on the left-hand side, it is evident from the figure that the rectifier will take by far the larger share of a given increase in load. At normal load, I, furnished by the rectifier and the motor-generator set in the ratio of 1 to 2, the voltage is E_1. Assuming that a heavy overload, drawing a current I_2, is now imposed on the system, the voltage will drop to E_2. The total current I_2 is more than twice as great as I_1, but the current supplied by the motor generator is increase only about 40%, while the current supplied by the rectifier is increased nearly 500%. From this it is evident that a change in the load on such a system changes the load on the

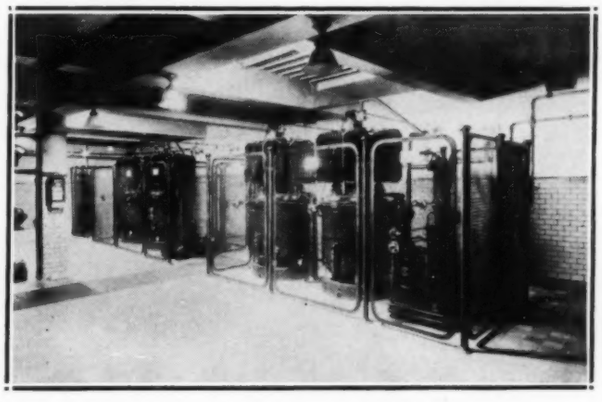

FIG. 6—Automatic Rectifier Installation in Brussels, Belgium.

motor-generator set only slightly, and as a consequence it can run at practically constant load, i. e., at its highest efficiency.

As mentioned before, in accordance with the fundamental principles on which the operation of a mercury-arc rectifier depends, energy cannot flow from the d-c. to the a-c. network, since current can pass only from the anode to the cathode. This, particularly, makes it possible to successfully parallel rectifiers when a-c. supply is derived from two independent net-works, whether of the same or of different frequencies. Should the frequency in one of the a-c. net-works vary or fluctuate in another function than in the other net-work, no troublesome or dangerous occurrences would have to be expected, such as motoring or flash-overs on the commutators in the case of synchronous converters.

There are at present throughout the world steel-enclosed rectifiers, in service and on order, with a total capacity of more than 600,000 kw. The number of rectifier cylinders operating in parallel with rotary converters or batteries, either in the same sub-stations, or over feeders, is about 900. These are distributed over about 450 installations, whose total capacity exceeds 450,000 kw. In other words, approximately 75 per cent of all rectifiers operate in parallel with other equipment.

In Fig. 4 is shown a rectifier installation in the Gold Street sub-station of the New York Edison Company. The rectifiers are rated at 570 kw. 240/260 volts. The primary supply is 3-phase, at 11,000 volts, 25 cycles. This installation operates in parallel with 4000 kw. rotary converter equipment. An air-cooled, electrically controlled induction regulator forms part of the equipment. The entire installation was completely furnished by the Brown Boveri Company, and was completed in 1924. It is used for supplying current for power and lighting. This figure also clearly shows the insulating feet on which the cylinders are mounted, and the vacuum piping connecting the two cylinders to the vacuum pump in the center of the picture, which parts are diagramatically represented in Fig. 2. The water radiators for the cooling of the anodes are also plainly visible.

Fig. 5 is a picture of the interior of the Harvey sub-station of the Commonwealth Edison Co. in Chicago, which supplies power to the Illinois Central R. R. electrification, recently completed. In this installation two 1500-volt, 1500-kw. Brown Boveri rectifiers operate in parallel with a 1500-volt, 3000-kw. 60-cycle rotary converter set. The synchronous converters can be distinguished in the back-ground, to the left. The primary supply at this sub-station is 33,000 volts, 3 phase, 60 cycles.

In Fig. 6 is given a view of the Palais du Midi automatic rectifier sub-station, in Brussels, Belgium. The installation consists of four sets of two rectifiers each. The first two rectifier sets were placed in operation in 1922; in 1924 another set was added; and the last addition was made in 1925. The cylinders are rated at 200 kw. 220 volts, each. The two original sets, installed five years ago, were hand controlled, while the newer sets are full automatic. Each set includes a 3/6-phase transformer, 5580-5300-5220/239 volts, and a 6-phase bus system to which the two rectifiers are connected through anode coils, thus ensuring a uniform distribution of the load.

This sub-station is used to supply current for power and lighting purposes. Attention may be called to the fact that the building is very low. This can be done with rectifiers because no elaborate and space-consuming ducts and blower arrangements are needed, the generated heat being dissipated and carried off by means of water.

*Parallel Operation of Synchronous Converters For Steel Mill Applications**

By W. B. SHIRK†

THERE is no special difficulty in operating synchronous converters in parallel. If several synchronous converters are to supply the same direct current system, they can be connected in parallel in the same manner as shunt or compound wound direct current generators and they are sometimes operated in parallel with such generators.

Synchronous converters used for supplying auxiliary direct current power in steel plants are usually compounded. In this case equalizers are required for the same reason as with compound wound direct current generators operating in parallel.

Where all the synchronous converters are fed from a common source of supply this factor usually requires comparatively little consideration. If the source of supply is steady and the resistance drop in the supply circuit is not excessive, points which may be counted on in a modern installation, hunting is never experienced under any normal operating condition and therefore satisfactory parallel operation will depend upon having transformers of the proper ratio for each converter, suitable reactance in the supply circuit and similar design proportions in the converters themselves.

If the synchronous converters are fed from a system where the frequency of the power supply varies, considerable speed oscillations or hunting will be produced in the synchronous converters just the same as in any other synchronous rotating apparatus.

An increase in speed of a synchronous converter causes the alternating current to lead in phase with respect to the induced E.M.F. This action strengthens the magnetic field of the converter and consequently causes the induced E.M.F. to be still further increased, and in turn the direct current output is increased. Under such conditions the primary input to the synchronous converter increases but not in the same proportion and hence there is no other variation in torque acting upon the armature shaft than that which can result from the variation in the losses in the machine with the load. This effect is quite small in comparison to the inertia of the armature. Under such conditions the amplitude of the oscillations may be very large and in some cases may cause the converted to "fall out of step." In the majority of cases, however, the effect of the oscillations are made evident by the fluctuations in the direct current voltage and load on the converter.

When considering the inertia of the armatures, every increase in speed causes additional kinetic energy to be stored in the armature and therefore causes the primary power input to be greater than the secondary output. Correspondingly, every decrease in speed causes the armature to loose its stored energy and in turn produces a contrary effect, namely, making the secondary or direct current power greater than the primary input. In both these cases the transverse armature reactions produced by the A.C. and D.C. active currents no longer balance each other and therefore the resultant axis of the resultant magnetic field oscillates and aside from the hunting action which takes place serious sparking occurs on the commutator.

The preceding analysis of the effect of wide variation in system frequency is not the only action which occurs with the machines on such a system. Let us assume that a relatively large synchronous converter is operating in parallel with several small machines. The larger the converter the lower the effective resistance when compared with a machine of much smaller capacity. Since the effective resistance of the large machine is less than the smaller machines, any increase in the system frequency causes the synchronous apparatus to increase in speed and consequently the large converters with their low effective resistance will immediately try to carry the entire load on the direct current system to which they are connected, therefore relieving the smaller machines of their share of the load. If the system frequency varies continually, undue heating will occur in the machines aside from the hunting action and poor commutation which is also taking place.

The problem of variations in system frequency was one that occupied the attention of everyone during the early stages of steel mill electrification, due to the fact that the generating equipment at that time was mostly driven by reciprocating engines and internal combustion engines. Since the electrification of steel mills has progressed to a very marked degree it has become necessary to increase the generating capacity of the power systems by installing additional generating units or to interconnect the system with some other source of power such as a central station power company. By increasing the generating capacity of the system to which the synchronous converters are connected the possibilities of variations in system frequency have been reduced to a minimum and therefore the successful operation of synchronous converters in parallel can be obtained if proper adjustments on the equipment have been made.

The successful operation of any type of equipment is usually judged by the number of units that are installed and the conditions under which they are operating. At this time it may be well to emphasize the fact the synchronous converters are operating in parallel successfully when supplying power to central station lighting loads, electrolytic plants, street railway systems and industrial plants.

In addition to the common source of supply as referred to in the previous part of this discussion, if the converter transformers are fed from a common bus or from circuits in parallel, the impedance drop in the supply circuit up to the transformer terminals being the same for all, does not effect the parallel operation of the machines.

After considering the source of supply and the constants of the feeder circuits, the next important

*Presented at Philadelphia Section, March 5th, 1927.

†Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

point to consider is the transformer ratio. It is very important that the transformer ratio be approximately the same for all synchronous converters to be operated in parallel. The ratio may be made different to correct for difference in the synchronous converter ratio between alternating and direct current voltage. For the same high tension supply voltage each converter must give the same direct current voltage and this is, of course, dependent upon its own ratio as well as upon the transformer ratio. Such a condition is desired over the entire range of load in order to maintain an uniform division of load and when such a condition exists there is an entirely automatic uniformity in the division of the load between the machines.

When several machines are to be operated in parallel and the voltage regulation of the respective units are not closely the same the machines may still be made to divide the load satisfactorily if there is sufficient reactance in the supply circuit.

In some cases the synchronous converters may not be exactly the same in their electrical characteristics and therefore some may tend to respond to sudden change of load more quickly than others due to the difference in the speed with which their fields follow the change in series excitation.

When considering the proper division of load between two or more compound synchronous converters operating in parallel, the first thought in order to obtain the proper load division, is to place a shunt across the series fields of one of the machines. In doing so this shunt is placed in parallel with the series fields on the other machines between the equalizer and the negative bus and therefore the anticipated results are not obtained. To make the proper adjustments in order to divide the load satisfactorily between several machines operating in parallel it is necessary to connect resistance in series with the series fields and by so doing the correct load division between the machines can be obtained.

When shunt wound synchronous converters are operated in parallel and if the machines have a slightly unequal ratio, with series reactance in the supply circuit the load on the respective machines may be adjusted as desired at any particular load by manipulating the shunt field rheostat, but this division of load will not be maintained automatically over the range but will ordinarily be satisfactory if the impedance of the several transformer circuits are not widely different.

In the case of compound wound machines, the load may be divided automatically with a close degree of accuracy over the entire load range. This is done as pointed out in the preceding part of this discussion by adjusting the series fields of the machine or machines which have a poorer regulation so that they will have a proportionally greater "in phase" voltage drop across the reactance in the circuit. The use of the series fields to obtain proper load division, utilizing the reactance in the circuit is, of course, corrected with the use of the series fields and reactance to obtain the desired voltage compounding. While the series fields are varied relative to one another to obtain the proper division of load they must all be strengthened or weakened together in order to obtain the desired voltage.

After considering the parallel operation of similar types of machines it may be well to consider the adjustments necessary in order to secure satisfactory parallel operation of a non-commutating pole synchronous converter and a commutating pole synchronous converter. In general, a commutating pole converter has less voltage drop from A.C. brushes to D.C. brushes than a similar non-commutating pole machine. This is due to the fact that when using commutating pole machines the brushes remain in a fixed position on the "no-load" neutral, therefore eliminating the inherent drop resulting from shifting the brushes forward to take care of load division. This means that when a commutating pole machine and a non-commutating pole machine are operating in parallel, the exact division of load usually cannot be secured through the entire range but adjustments can be made to the commutating pole converter to take more than its proportionate share at the larger loads which in general it will be better able to do.

When two machines are connected in parallel it has been found that if there is considerable difference between the respective values of reactance in the A.C. circuit for each machine, that satisfactory load division will only occur over a very small portion of the load range. However, as the values of reactance in the A.C. circuit for two machines approach each other, the greater will become the range over which satisfactory load division will occur. In cases where the load change is not rapid the operator may maintain a uniform division of load by manipulating the shunt field rheostats.

Synchronous converters used in steel mill applications usually have the field excitation set so that with an average load the converters will be operating at unity power factor. The average load for a converter is found by dividing the K.W.H. output of each machine by the number of hours the machine was operating, and which in general terms is the "capacity factor."

It is very essential that unity power factor be maintained on the machines very close to full load output otherwise undue heating will occur in the machines. By increasing the phase displacement irrespective whether lag or lead the average as well as the maximum armature heating increases greatly. This means that in order to avoid any hazardous heating in the machines the shunt fields must be adjusted so that the current comes in phase with the voltage close to full load on the machine.

With increase of phase angle the alternating-current input increases with the direct current output remaining constant and in turn the heating increases very rapidly for differet parts of the winding. Take for example, at 85% power factor and full load output on a 6 phase converter, the "tap coil" heating will be approximately 300% of the normal heating and the average heating of all the armature conductors will be approximately 240% of the normal heating.

When installing synchronous converters commutating pole or non-commutating pole it must be kept in mind that the regulation depends entirely upon conditions external to the machine, the most important of these being the ohmic drop and reactance between the converters and the source of supply. It is, therefore, usually necessary to make adjustments on the old as well as the new machines in order to obtain the best results when machines are required to operate in parallel.

*Parallel Operation of D.C. Generators and of D.C. Generators with Synchronous Converters**

By ERNEST PRAGST†

A DISCUSSION of the fundamental laws governing the parallel operation of d-c. generators and of d-c. generators with synchronous converters can be divided into three parts and thereby facilitate and clarify the treatment of the subjects. These three parts relate to the parallel operation of: (a), shunt wound generators with shunt wound generators; (b), compound wound generators with compound wound generators; (c), compound wound generators with compound wound synchronous converters. In this paper the subjects will be treated in this order.

A change in the division of load between d-c. generators can be made through a change in the relative speed of the machines operating in parallel without altering the rheostat settings, or by holding the speeds constant (in practice, approximately constant) and changing the relative settings of the rheostats, and, so, field excitations of the machines. The latter is the usual method of shifting load from one to another d-c. generator. Both methods accomplish the same end by the same means,—namely, through a change in the relative electro-motive forces generated by the several machines operating in parallel. Increase the field excitation of a d-c. generator, when operating in parallel with others, and its output is increased. The primary problem in any question involving the parallel operation of d-c. machines usually will be found to be concerned with difficulties incident to maintaining a proper division of load and operating stability. It is principally with these questions that this paper deals.

Parallel Operation of Shunt Wound Generators

Machines having drooping voltage characteristics, —which is to say, poor voltage regulation—operate in parallel with a great degree of stability. Stability increases as the regulation becomes poorer. This becomes evident as soon as one realizes that to take a greater proportion of load a machine must generate more voltage. If a generator with a fixed field setting operates so as to decrease its voltage with an increase in current output, it follows obviously that it has no tendency to bring about a condition of instability when the load distribution between it and other machines operating in parallel is suddenly altered because of some small change in load or the speed of any of the machines. An inherent characteristic of a shunt wound generator is its drooping voltage characteristic. Because of this, great stability can be expected when they are operated in parallel.

If the voltage regulation characteristic curves (curves plotted between terminal voltage and ampere output with a fixed rheostat setting) of two shunt wound generators are identical, they will share equally a varying load throughout their complete capacity range from no-load to full-load, provided their rheostats are once adjusted for an equal division of load at some one value.

Should the regulation curves differ materially, it might be possible to obtain an equal division of load for one value of load, but for no other without a readjustment of the rheostat of at least one of the machines. Fig. 1 shows the regulation curves of two shunt wound generators having dissimilar characteristics. In both cases such rheostat adjustments

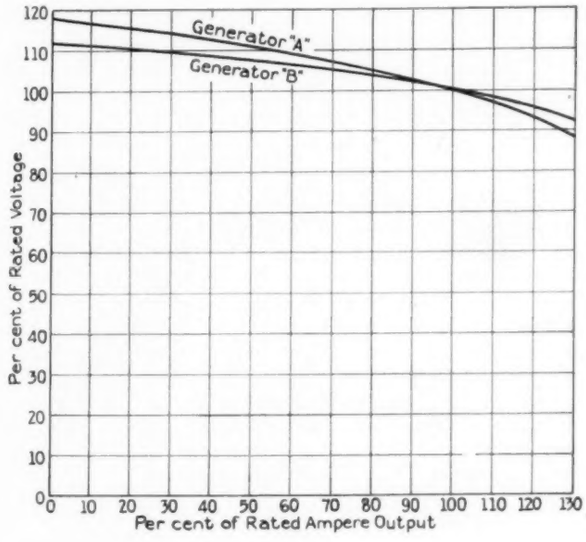

FIG. 1.

have been made as will result in 100 per cent (rated) voltage when the current outputs of the machines are 100 per cent (normal). If the rheostat positions are not changed, Generator "A" will have a greater output than Generator "B" in the case of loads less than normal, and, in the case of loads in excess of normal, Generator "B" will have the greater output. To find the division of load, it is only necessary to determine the relative outputs corresponding to like voltages. For example, when Generator "A" is carrying 55 per cent of its normal load, Generator "B" will be carrying only 25 per cent of its normal load. The voltages of both, of course, will be the same—namely, 110 per cent of rated voltage. In practice this condition should not prove detrimental to satisfactory operation. If the rheostats are set so as to result approximately in an even distribution of load under full-load conditions of operation, it is of little practical interest whether the load is proportioned equally during periods of light load operation or not, as all machines will be operating with outputs less than those for which they were designed and no tendency to instability should exist to cause apprehension.

*Presented at Philadelphia Section, March 5th, 1927.

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Parallel Operation of Compound Wound Generators

If compound wound generators were built with weak series fields so that their voltage characteristic curves would droop between no-load and full-load, they could be paralleled as easily as shunt wound generators and with nearly the same assurance that stable operation would ensue. Equalizers would not be necessary. But, in practice, compound wound generators are not made with such characteristics. Compounding is employed deliberately to overcome the drooping characteristic of the simple shunt-wound machine—usually to secure, without rheostat adjustment, a voltage at full-load not less than at no-load. In other words, machines are often over-compounded, the over-compounding being employed to compensate for the increase in the potential drop over lines as the power they are carrying is increased. The outstanding uses of over-compounded machines are to be found in railway and similar services. As soon as a generator is flat or over-compounded, it becomes impossible to operate it with assurance in parallel with others, unless an appreciable resistance is introduced between the machines or a common equalizer bus is used. It is universal practice to operate all paralleled compound wound generators installed in the same station with a common equalizer circuit. If several stations feed into the same network, sufficient resistance is usually present in the connecting feeders to eliminate the necessity of carrying the equalizer circuit between stations. Should the stations be located near each other, connected by very low resistance circuits, and contain over-compounded machines of appreciably different characteristics, operating instability might result. The condition can often be improved, if not entirely overcome, by the introduction of a low resistance equalizer circuit between the stations.

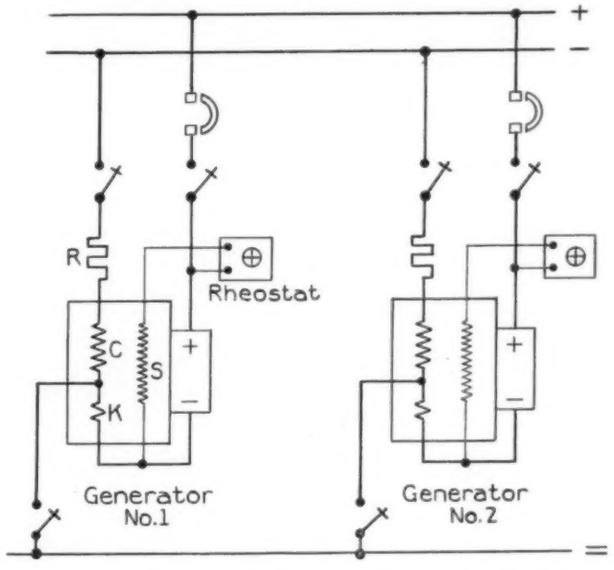

FIG. 2.

Fig. 2 is a diagram of the connections of two compound wound generators arranged for operation in parallel. In this diagram (S) is the shunt field, (K) the commutating field, (C) the series field and (R) a paralleling resistor of Generator No. 1. A commutating field has been shown because they are now almost universally used. Its omission will not affect the matters with which we are here concerned. As a rule, it is necessary to add resistors (R) in the positive leads of all but one of the generators which are to operate in parallel to secure a proper division of load. These resistors are chosen of such values as are necessary to secure a division of current between the several series fields, paralleled between the negative and equalizer buses, proportionate to the capacities of the several machines.

After these connections and provisions have been made, successful parallel operation can be expected only provided the characteristics of the machines to be paralleled are not dissimilar. Fig. 3 shows the compounding curves of two generators which will illustrate what I have in mind. Both generators are over-compounded 10 per cent. With appropriate rheostat settings, both will generate 100 per cent volts at no-load and 110 per cent volts at full-load. It is only at these two points though that the voltages of the two machines will coincide for the same or proportionate current outputs. Only at full-load will they share properly the total load. In the case of over-loads, Generator "B" will carry more than its proportion of the load; in the case of light loads, Generator "A" will carry more than its proportion. The condition is not conducive to stable and successful operation.

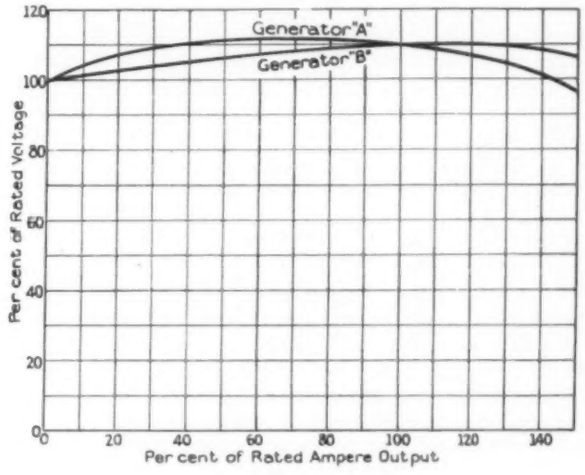

FIG. 3.

It should not be imagined that a situation of this sort can only occur in those cases where the units are mechanically dissimilar, as, for example, when great discrepancies exist between the sizes and speeds of machines. These are the conditions under which it is most probable to happen but it can be encountered in the case of units which to all appearances are duplicates. Differences in the magnetic properties of cast-iron field frames, in air-gaps, in brush settings, etc., may be sufficient to account for the difficulties experienced when attempting unsuccessfully to parallel machines which superficially appear to be duplicates.

What are the means to be employed to prevent the inconveniences incident to an inability of machines to parallel successfully? If it is known that new machines must parallel with others in the possession of the user, the obvious thing to do is to anticipate trouble and guard against it. Advise the

manufacturer of the new machine that it must parallel with others, so that he can have the opportunity of incorporating in his machine electrical characteristics similar to those of the existing machines. He can usually do this without much trouble—certainly with less trouble than the user might have later should he find it necessary to alter a machine's characteristics to obtain successful operation. From the point of view of the user, the precaution he is asked to make seems simple; and it is simple. But, simple as it is, it is a precaution that is often neglected, particularly in the case of exciters which must operate in parallel under the control of a voltage regulator. If the generators to be paralleled have been manufactured without reference to their possible operation together, they might or might not function successfully. The simplest and most direct method of determining whether machines will operate together is to try to operate them together. Should trouble be experienced, one had better take characteristic curves of each machine and compare these curves to determine wherein the dissimilarities of the several machines lie. The solution of the problem is to be had through changing the characteristics of some or all of the machines so that they more nearly resemble each other electrically. This end is accomplished largely through experimentation. Changing compound and interpole field shunts, shifting brushes, removing or adding pole shims, will usually be sufficient to bring the characteristics of the several machines in near enough conformity to effect successful parallel operation. It is largely a case of cut and try, tedious, but, in most cases, not at all hopeless.

Parallel Operation of Generators With Synchronous Converters

The question of parallel operation of d-c. generators with synchronous converters is a perennially occurring one. It will probably be with us to embarrass the application engineer as long as d-c. generators and converters are made. The only safe advice an application engineer can give to his client is that he had better avoid attempting to parallel the two types of apparatus. Perhaps, a more accurate answer to the question is that it can be done if all conditions are ideal. In practice it is seldomly successfully accomplished. However, there are just enough cases where it has been done to encourage engineers to try it. The reason why successful results are so rarely realized is because it is seldom possible in ordinary practice to maintain the necessary ideal conditions, or conditions approaching near enough to the ideal to avoid trouble.

The reasons for the difficulties experienced in most attempts to parallel converters with generators become at once apparent when we consider some of the fundamental characteristics of the two types of apparatus. The converter is, strictly speaking, an electrical conversion machine. As usually employed, it converts power in the form of alternating current into power in the form of direct current. The conversion is direct from electrical to electrical energy with a metallic electrical path between the two systems. A practically constant ratio exists between the voltages of the a-c. and d-c. system, irrespective of load changes. Voltage changes and disturbances in one system are instantly reflected in the other. Neglecting some special forms of synchronous converters and their transformers, in which provision is made to vary at will the voltage conversion ratio, we may say without appreciable error that, if we hold the a-c. voltage input to a converter equipment constant, the d-c. voltage will remain the same irrespective of load. Conversely, if we alter the a-c. voltage, the d-c. voltage will vary with it in a constant ratio.

Now, let us consider a d-c. generator. For our purpose it is immaterial whether it is driven by a turbine, an engine or a motor. It is only necessary that it be driven at approximately constant speed. A d-c. generator converts mechanical power into electrical power in the form of d-c. current. No relation whatsoever exists between the voltage of the generator and that of the driving source. No electrical or magnetic path exists between the d-c. and a-c. systems in the case of a generator driven by an a-c. motor, and, so, voltage fluctuations in one system are not reflected in the other. The two electrical systems are entirely independent of each other.

After refreshing our minds with a review of these elementary characteristics of the two types of machines and noting the fundamental differences between them, the reasons for the difficulties—which almost inevitably ensue when parallel operation is attempted—should become apparent. The explanation rests on the fact that for machines to operate successfully in parallel, their terminal voltages should be the same with corresponding loading. This will be the case with synchronous converters in parallel fed from a common source; it will be the case with generators of like shunt or compound characteristics; it will not necessarily be the case with converters and generators in parallel. When it is, parallel operation will be possible; when it is not, attempts at parallel operation will be in all probability unsuccessful.

DISCUSSION

F. O. Schnure*: There are two questions that come to my mind. I was wondering whether the mercury arc rectifier had been developed to take care of 250 volts, 25 cycles. That is the first question. The next question is on the parallel operation of motor generator sets. I am, by no means, an expert on that matter, at all, but we have found the best way to parallel motor generator sets is to shift the brush holders. We have an order now on an application of voltage regulating device to parallel one motor generator set with another one, with a bank of three or four in another mill about one thousand feet away. I want to ask whether this procedure has been resorted to very often.

Ernest Pragst: Shifting brushes is one of the of the simplest and, so, should be one of the first things to try in attempting to make machines parallel. The special device you refer to is nothing more than a mechanism to accomplish automatically what is usually done manually—namely, vary the excitations of the machines to obtain the proper division of load.

F. O. Schnure: What we really are doing is keeping one machine from taking more than a full load.

E. Pragst: Yes, but you are accomplishing your result through a change in machine excitation.

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*Supt. Elec. Dept., Bethlehem Steel Co., Sparrows Point, Md.

O. K. Marti†: There is no question that for such low voltages, around 200 v., a rectifier compares unfavorably with a rotary converter, in space and efficiency. However, there is less attendance required, and in the case of an automatic installation the automatic equipment is simpler and consequently more nearly fool-proof. Furthermore, in congested urban districts, where no substation can be built, a rectifier can be placed anywhere, for instance in the basement of a building, since it makes no noise and since the generated heat can easily be taken care of by water cooling, instead of by air cooling with its necessary large fans and ducts. Besides, a rectifier requires no special foundations.

P. T. Vanderwaart*: I came down here to listen and learn. I have learned a lot. It might be of interest to bring out another phase of the situation which has not been mentioned as yet. I refer to the possibility of sometimes wanting to transfer power in both directions. We have an application right now for a 500 k.w. synchronous motor driven generator, which is to be used as an inter-connection between an A.C. and D.C. system and the A.C. system is comparatively a small one, the only generating power on it being steam turbine driven.

E. Pragst: Let us assume that you have a motor-generator that is flat or compound wound. If you operate the set inverted, you reverse the flow of current through the series field, but do not reverse the flow of current through the shunt field. Therefore, you have the equivalent of a machine with a differentially wound field which means that as the load is increased, the field of the machine (motor in the case in question) becomes weaker. It follows that the speed at which the set is operating will increase—perhaps to the point of wrecking the set. The customary thing to do, when one operates a set inverted, is either to short-circuit the series field or reverse its connections.

R. M. Fuller‡: In paralleling motors there must be considerable heating, is there not? If so, how would it be taken care of? Would it be possible to parallel entirely two 60 cycle systems to the mercury arc rectifiers, on the D.C. end of it? If so, what would result in the varying frequency? Suppose you had two different sources of A.C. supply and you wanted to feed a common D.C. bus, can you parallel them through a mercury arc rectifier?

O. K. Marti: Yes, you can do so. One rectifier would take a little more load than the other, but it is possible, for instance, to parallel 25-cycle and 60-cycle a.c., which is very difficult in the case of rotary converters. In case of a change of frequency in one system, no difficulties as to parallel would be experienced, and falling out of step would not have to be feared.

John C. Reed§: I am going to ask a question, but before I do, I will do some explaining. We have three motor generator sets, presumably all alike. I have learned in trying to solve this trouble that two machines never were exactly alike. These three machines look alike, and are supposed to be alike, and I thought were alike, but evidently, were not alike because they would not hitch up together. The synchronous motors all ran from the same source of power, so we presumed that the speed was all o.k. We could not make the three of them run together by juggling the brushes, but we found that the breakers would not kick out more than once every day. So far as satisfactory operation was concerned, we could not get it. I talked to everybody I thought might have something about this thing and never got anywhere with it. Finally one of the engineers made the suggestion (I thought he was trying to get rid of me when he made this suggestion) that I move my equalizer connection to the other side of the commutator field, and I went home and did that and it worked beautifully.

J. M. Donnelly*: I would like to ask a question in reference to the parallel operation of synchronous converters, one of 25 cycle, and one of 60 cycle. In asking several people about this, they thought it would be a good thing to stay away from, but I would like to see if any of the factories have had any experience on that. It is a natural condition that exists all around the line. Can any of you gentlemen answer that question.

E. Pragst: I do not think it will be practicable to do what you suggest. The only condition under which successful operation will be possible will be that in which the voltages of the two systems are maintained constant, or at least, vary together. In practice I do not believe that this is possible.

W. H. Burr†: The question was raised with reference to operating two systems in parallel—two different generating stations. I came here tonight to try and find out how to operate a steam station in parallel with rotary converters, and the first speaker advised that he would keep away from it. We have had that in operation, I suppose, for about six years—a rotary station supplied from an auxiliary source of power, a D.C. station, and have fairly satisfactory results. Nevertheless, I agree with the speaker, if you keep the two operating separate you would have less interference. I have had experiences in paralleling D.C. outfits. As John Reed said, they supposedly look alike, and ought to act alike and do not. And as one speaker said, we should be very careful in specifying when we purchase new equipment, and to say this is to operate in parallel with other equipment or operate separate; and not only that, but we must be very careful to keep the circuits of the same resistance. In one particular instance we had considerable trouble. After working several months we found we eliminated practically all our trouble by changing the length of the equalizing circuit and cutting down the resistance of the equalizing bus, which practically cured all our trouble.

I would like to ask Mr. Marti what the maintenance on the mercury arc rectifier amounts to as compared to the maintenance on the rotary converter; also the life that one can expect from a mercury arc rectifier. We are led to believe that with the ordinary glass rectifier we can only expect a certain life out of the tube, and I am curious to know what life is gotten out of the steel cylinder used for the present rectifier. I have watched the mercury arc rectifier develop for a number of years, and recall very vividly trying to see into an enclosed building in order to find out what the developments on the

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*Elec. Engr. Dept. of City Transit, Philadelphia, Pa.
†Supt. Elec. Dept. Lukens Steel Co., Coatesville, Pa.

steel tube rectifier were. I had about given up hopes we would ever have a successful one. I am very glad, however, to learn tonight we have, because with the equipment it is very difficult to keep two machines operating on different circuits, and if it can be done it is a step forward for the rectifier.

O. K. Marti: We have had rectifiers in operation since 1911. One of our rectifiers has been in operation since 1913, I think, and is still running, so far as I know, without any part of the rectifier proper having been replaced. However, it might be necessary at some time or other to replace certain parts of the auxiliary equipment, especially of the rotating apparatus, such as the contactors, etc. The anodes of the rectifier will not wear down, as far as could be checked during the fifteen years' experience with rectifiers. The diminution of the mercury cathode is zero, because the mercury which vaporizes is condensed and flows back into the cathode receptacle. The seals, which are secured by means of mercury, also cannot suffer in any way during operation. It is true that there might be a slight loosening of the seal which would permit some of the mercury to flow into the cylinder, but this would of course cause no trouble whatsoever, as this mercury will merely be collected with the other mercury in the cathode receptacle. This might make it necessary to replace a corresponding amount in the seal, which amount can be read directly from the gauge conveniently mounted on each seal.

R. M. Fuller: I would like to ask Mr. Marti what is the smallest size they supply this rectifier for, say, 220 volts?

O. K. Marti: The smallest size for 200 volts is about 100 k.w.

D. M. Petty: I might add something to what these gentlemen told about not being able to operate different units in parallel. We have a station now in which we had four reciprocating engine driven units, two 1000 k.w. rotaries and one 1500 k.w. motor generator set, all on the same D.C. bus. I am not bragging about the kind of operation we got, but we got away with it. This particular 1500 k.w. set was also arranged so we could transfer power back to our 25 cycle A.C. system, but that was seldom used. A question I would like to ask in connection with converters, is there any particular disadvantage in using shunt wound rotary converters in parallel operation?

Wm. B. Shirk: There is no particular disadvantage. I really am interested in the shunt wound rotary converter for this reason: A shunt wound motor will always have a leading power factor. You will have that in the machine itself. Whereas it is just the opposite with a compound wound motor.

D. Petty: There would be no difference in regulating?

W. B. Shirk: That can be taken care of by the proper adjustment.

K. R. Deininger*: I have not much to say, except that in the case of a 600 volt rotary converter one station 60 cycle, the other 25 cycle, directly connected with fairly heavy cable d.c. we got 600 killos. The first slight variation is going to shift the load from one system to the other. I believe it could be gotten away with very easily by using shunt wound machines.

*Philadelphia Rapid Transit Co., Philadelphia, Pa.

L. R. Woodhull*: One thought that occurs to me in connection with the use of shunt rotaries versus compound rotaries is this: It seems to me it is just the same question you have to deal with in all engineering matters. Is the advantage you gain worth what it costs? You have a definite limit that you cannot exceed, and if you have a tripping voltage characteristic in your machine you have to put much more copper in your system to maintain working limits. I have a case under investigation right now where complaint was made as to power voltage regulation to the amount of feeder necessary to bring the voltage regulation within workable limits. I do not know if we can get a machine that will take care of this emergency, or if we can afford to spend considerable money to bring that voltage characteristic up to what we are accustomed to get out of a compound rotary converter.

D. M. Petty: I would like to put one more problem up to these speakers, and that is they tell us, when we buy a machine we should be sure to specify all the characteristics of the old machines. Now I would like to have a little discussion on how to get those characteristics.

O. K. Marti: It is usually only necessary to give the manufacturer who is building a new machine the name plate rating and the serial number of the old, and he can usually get that from the manufacturer himself, and that information would be practically the shape of the curve plot between the voltage and current.

D. M. Petty: Suppose the shunts as furnished with the machine had been considerably altered and changed from when they were put in service. That is the point that worried me. In other words, I want to find out the easiest way to make a voltage characteristic curve.

O. K. Marti: All you have got to do is to set the field—setting the voltage corresponding to that load.

D. M. Petty: I know that, but want to know an easier way to do it. Generally speaking it is a little hard to isolate one machine from the other.

W. B. Shirk: Mr. Chairman, I might state that I had some experience in obtaining the characteristic curve for a machine in service. I have one particular test in mind where it was absolutely necessary to obtain the characteristic curve of a gas engine driven generator so that the characteristics of a future machine could be determined in order that the machines could be made to divide the load properly. I went to this particular plant one Saturday afternoon to obtain the data on the gas engine driven generator, but when I arrived there I found the machine was only carrying about 25% of its rated load. I then advised the electrical superintendent that in order to obtain the characteristic curve the load on the machine should be increased in small increments. He stated that he could increase the load on this machine and I told him to go ahead and do it. He then called up another substation located about one quarter of a mile away and told them to trip off two of their sets. The operators obeyed orders and in turn the load built up very rapidly on the gas engine driven generator, but we were able to obtain

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simultaneous readings of volts and amperes from one-half load up to load and one-half which was just what he wanted. Due to the gas engine driven generator being overloaded we thought we were going to drop the entire load of the blast furnace, but it so happened that the generator breaker was set high enough and therefore we were able to put the other two sets back on the line before anything serious happened.

R. M. Fuller: Is it impractical to parallel a synchronous motor driven M. G. set with a synchronous converter, both parallel on the A.C. side?

E. Pragst: Yes, I would say so. I believe I answered your question in my paper.

Centrifugal Compressors

By BATT L. SPAIN*

TURBO-BLOWER is a term generally applied to the blast furnace blower of the centrifugal type. The characteristics and the advantages of this machine are generally understood and its worth has been proven to the extent that it has become standardized, but there are many other applications of blowers of the centrifugal type, some of which will be found in the steel mill.

Instead of confining this paper to a single application we shall discuss:

1. Some of the interesting problems encountered in the development of the centrifugal compressor or blower.
2. The contribution of the producers of steel and other materials to the development of the art.
3. Steel mill applications.
4. Available drivers.
5. Auxiliary features.
6. Other interesting applications.
7. Future developments.

In 1905 the General Electric Company undertook the development of a centrifugal blower which would produce higher pressures and require less power than the fan type and the term centrifugal compressor has been used to distinguish this machine from the ordinary fan. When the initial research was begun there were no machines of this type manufactured in this country and the few units which had been built abroad were not entirely out of the experimental stage. At that time very little was known concerning the actual air delivery of other types of compressors and it was customary to rate them in terms of displacement.

As it was intended to substitute the centrifugal compressor for machines of the positive or displacement type, it was necessary to determine accurate methods of metering air in order that the new machine might be properly rated and applied.

Improvement in impeller design was the next step and studies were made of inlet and exit blade angles; tests were made on impellers with various numbers of blades; effect of impeller clearances, impeller air velocities, and eddies at the impeller inlet were investigated; shrouded and open impellers were tested and finally a wheel was produced which gave fairly good results, and it has been steadily improved.

Fan blowers had little provision for the conversion of kinetic energy or air velocity at the impeller exit, into useful work, or pressure, consequently it was necessary to make studies of various means of effecting velocity conversion. Expansion nozzles surrounding the impeller were, of course, necessary, and it was found that nozzles formed by inserting blades between rings produced the desired result. These nozzles are called discharge vanes.

Fairly high efficiencies are obtained with this arrangement over a small range of load, but the slope of the efficiency curve on either side of the peak is very steep. Because of this defect variable discharge vanes were developed which permitted of changing

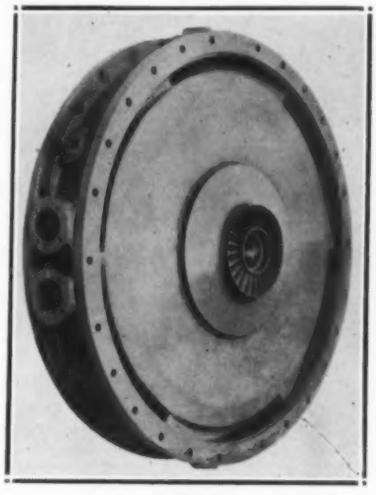

FIG. 1.

the inlet angle and area of the conversion nozzles to correspond with changes in load, and while some improvement was realized with this arrangement, the results were dependent upon the diligence of the operator or the addition of a rather complicated automatic mechanism, the wear of which produced uncertain results. Furthermore, it was found that stationary discharge vanes of the most rugged construction frequently broke as the result of blade vibration and fatigue and it was felt that greater difficulty would be experienced with blades held by the mechanism for adjusting the blade angle. This arrangement was therefore abandoned.

As the result of more recent research, blades have been eliminated and the expansion or diffuser passages are designed to allow the air to follow unobstructed paths. This form of expansion nozzle produces a better pressure characteristic, a very much

*General Electric Co., Schenectady, N. Y.

flatter efficiency curve, and less noise; however, the diameter of the compressor casing must be materially increased, with the result that more labor and material is required in the manufacture of the compressor. Figure 1 shows an impeller, one side of the conversion passage and a diaphragm of a multi-stage compressor. Figure 2 shows the adiabatic shaft and hydraulic efficiencies of a single-stage compressor with discharge vanes (Set No. 115) and a similar machine representing the results of more recent development of a conversion passage without the blades (FD-387).

Shaft efficiency is the ratio of theoretical power for adiabatic compression to the actual power de-

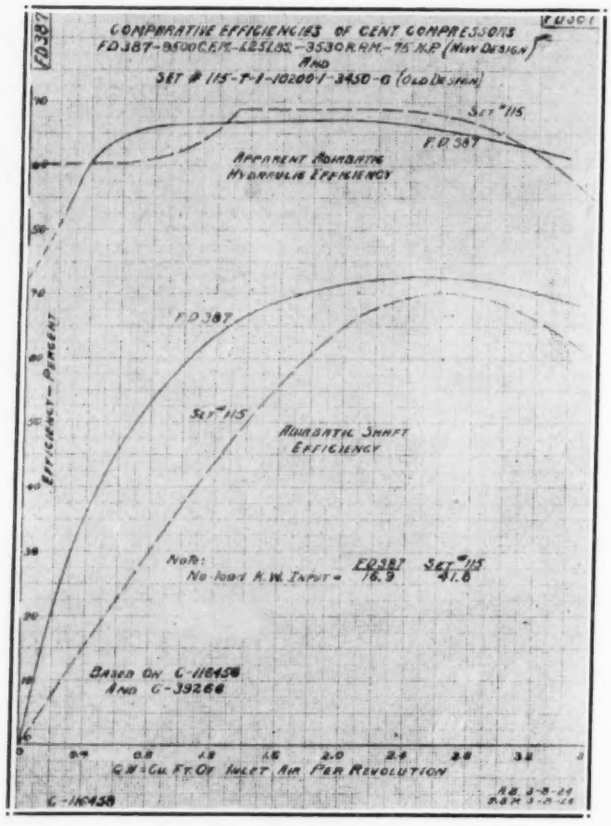

FIG. 2.

livered by the driver. Hydraulic efficiency is the ratio of the actual work of compression accomplished (or approximately the pressure rise obtained) to that theoretically possible with a perfect impeller having radial blades, and of the same diameter and running at the same speed as the actual wheel. The actual discharge pressure curve is proportional to the hydraulic efficiency curve.

The centrifugal compressor is simple in construction but the efficient compression of air with this machine has been made possible only by extensive research and developmental work. The General Electric Company have kept employed on compressor reasearch work an average of five engineers over a period of twenty-one years. These men are not engaged in the design of commercial machines, as this work is done by another group. Some of the investigations will be briefly described to show that the shaft efficiencies now obtained represent the aggregate of many small improvements.

Figures 3 and 4 show respectively a sectional drawing and an exploded view of a single-stage compressor. Spacers are inserted in the conversion passage in order to stiffen the casing. The shaft efficiency at rated load of a given unit with round spacers was found to be 2% lower than the same

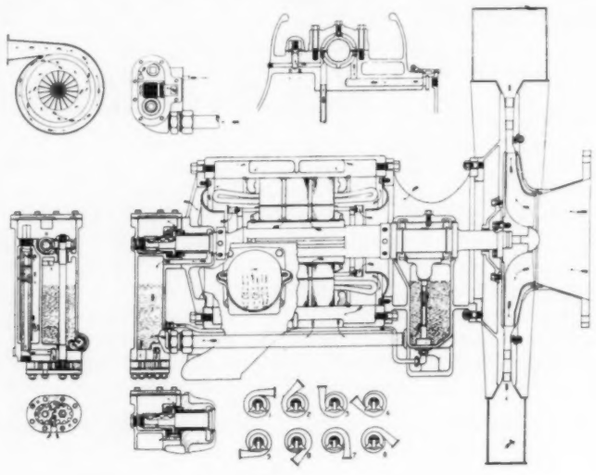

FIG. 3.

machine with no spacers. Fish-tail spacers resulted in no loss at full load, a slight gain at partial load, and a small loss at overloads.

In order to determine the kind of finish to be given the air passages, tests were conducted on a machine with diffuser surfaces finished to various degrees of smoothness. The surface treated was that extending to a diameter of 41 inches beyond the exit of a 30-inch impeller. The rough surface showed a

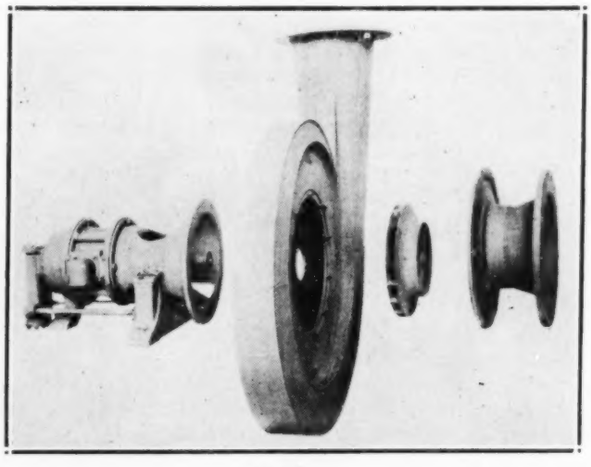

FIG. 4.

loss in efficiency of 15½% as compared with the results obtained with a very smooth surface.

Narrow impellers are materially improved by shrouding, whereas the gain with wide impellers is slight. Very wide impellers show no improvement as the result of shrouding.

The width of a diffuser passage determines the capacity to some extent, but there is a wide range of passage widths through which the capacity re-

mains practically constant and other factors, such as inter-stage passage areas and impeller dimensions, become the limiting features.

Eddies at the impeller inlet are very detrimental, for instance, a single-stage machine having a blast gate between an elbow and the inlet nozzle of the compressor reduced the efficiency to 55%. The same inlet piping arrangement, with the exception that the blast gate was located before the elbow, reduced the efficiency to 60%. The blast gate was opened the same amount in each instance and the results showed the effect of disturbance at the impeller inlet caused by the blast gate. For this reason impellers are designed to receive the air with the least possible shock, and this accounts for the use of entrance buckets on the impellers.

Impellers with various numbers of blades have been tested to determine the comparative results on pressure and efficiency curves. For example, a single-stage, 4200-c.f.m. unit showed at rated load a loss in pressure of 3¼% and in efficiency, 2%, by reducing the number of impeller blades approximately 40%. In another instance a reduction of 26% in the number of impeller blades reduced the shaft efficiency 7%.

Such tests as these do not result in conclusions which are applicable to centrifugal compressors in general, but they determine the best combinations of air velocities, impeller inlet design, impeller width, number of impeller blades, fluid angles, diffuser dimensions, inter-stage passage shapes and dimensions, etc., for a specific type.

The development of this apparatus has been costly, and while the results have been gratifying, further improvement will undoubtedly result from the research work which will continue.

Although the design of a compressor of given size is based on research tests, the performance of a machine of new design must be determined by complete tests on the complete unit. Adequate testing facilities and a technically trained testing force are maintained for this purpose. These facilities include high-pressure boilers, super-heaters for 725° F. total temperature, condensers suitable for vacuums up to 29 inches, air mixers, air preheaters, cooling water heaters, tank scales for weighing the condensed steam, etc. A force of thirty-three men is required to properly conduct complete tests on a blast furnace blower with its driver, and the cost of determining the performance of a new unit is between five thousand and six thousand dollars. Fig. 5 shows the testing crew and a blast furnace blower.

When the 3600-r.p.m. compressor was first introduced this speed was considered by many to be excessive. Only machines of moderate capacity were designed for this speed, but it was necessary to employ the best materials available. The first centrifugal blast furnace blower in this country was built for the Empire Steel and Iron Company. It consisted of six stages and was designed for a maximum air pressure of 25 pounds gauge, a capacity of 22,500 cubic feet per minute and a maximum speed of 1950 r.p.m. Its speed was partially limited by that of the available 2000-h.p. turbine. As better materials became available they were employed, and in 1910 the three blowers for the Iroquois Iron Company were designed for a maximum capacity of 45,000 c.f.m. at 30 lb. pressure and a maximum speed of 3250 r.p.m. Notwithstanding the higher pressure of 30 lb. and the 5400-h.p. turbine required, only three stages were used in the air end.

The air pressure for this service has remained at a maximum of 30 lb., with a few exceptions, but the speeds have been gradually increased with the designers' knowledge of improved materials and today the maximum speed of the largest blower contemplated is 4500 r.p.m.

The producers of steel and other materials have also made higher steam pressures and temperatures possible, and these factors, combined with the improvements in blower and turbine design, have resulted in a reduction in steam consumption of 38% at normal operating conditions, as compared with the performance of blast furnace blowers designed in 1910.

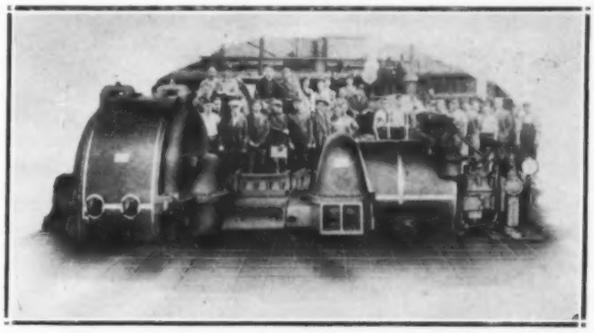

FIG. 5.

Smaller multi-stage compressors in sizes which ten years ago were designed for 3600 r.p.m. are now built for speeds of 8000 to 10000 r.p.m., and some of the single-stage units run as high as 35000 r.p.m.

The construction of these machines requires the same degree of skill and manufacturing facilities used in the production of turbines, but the manufacturing problems have decreased.

Although the r.p.m. of centrifugal compressors has been increased, the peripheral speeds have not been materially increased and the stresses are quite moderate. A few special machines have been constructed which represent novel practice and these will be referred to later.

By utilizing higher speeds, small centrifugal compressors for relatively high pressures have been made available, because of the resulting increase in efficiency and reduction in cost. An interesting example of the effect of speed on efficiency concerns a unit of 1200 cu. ft. per minute capacity at 3 lb. pressure. By using a single impeller at 3500 r.p.m an efficiency of 45% was obtained. Three impellers in series at 3500 r.p.m., designed for the same capacity and pressure, had an efficiency of 60%. Again, by using a single wheel of small diameter and running at 20000 r.p.m., an efficiency of 70% or better would be obtained.

Where machines of considerable size are concerned, the cost reduction resulting from the use of higher speeds is frequently offset by the increased cost of refinements such as the use of a large number of stages in the turbine, provision for cooling the compressor casing, applying a better finish to the air passages, the provision of ample diffuser capacity, etc. Therefore, while high speed in itself is not

necessarily a measure of efficiency, it enables the manufacturer to produce a machine of higher efficiency at reasonable cost.

The blast furnace blower is probably the most spectacular application of the centrifugal compressor in steel mills, but it may be used to advantage for other purposes, for instance:

Some interesting results have been realized as a result of using centrifugal compressors to blow Bessemer converters. Last fall the Jones & Laughlin Steel Company installed two 45,000-cu. ft., 35-lb. centrifugal compressors at Woodlawn, Pennsylvania,

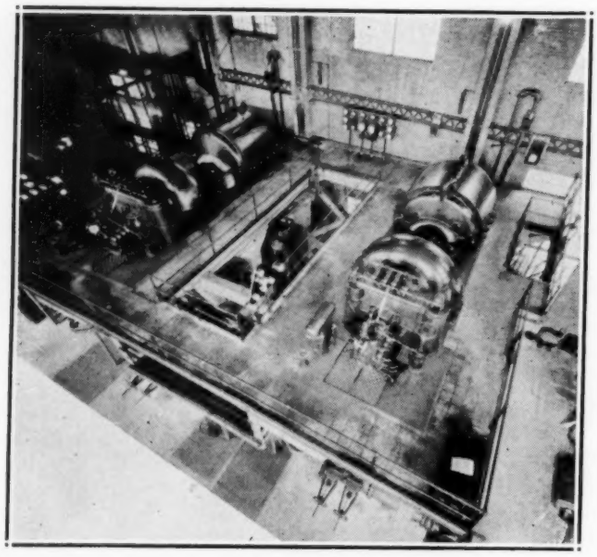

FIG. 6.

with the idea of using one unit on each converter. Presumably the capacities specified were based on the displacement of reciprocating engines; furthermore, these machines have large overload capacities and when two converters are blown simultaneously one centrifugal compressor, in parallel with a reciprocating blower operating at 6000 cu. ft. per minute displacement, furnishes an ample supply of air. The second centrifugal compressor in parallel with a reciprocating blower is supplying air for one of the blast furnaces. The average operating pressure of the converter blower is 30 lb. gauge. The better steam economy of the new blowers has resulted in eliminating delays in the steel mills formerly caused by lack of steam. Figs. 6 and 7 show the J. & L. blowers and foundation.

The centrifugal gas exhauster and booster have been quite generally standardized in the manufacture and distribution of gas. This type of exhauster readily lends itself to close pressure regulation and its maintenance and operating costs are low; furthermore, it is an efficient tar extractor and several plants are using the centrifugal exhausters in combination with washer coolers with the result that tar extractors are not required.

Motor-driven blowers (Fig. 8), are used in large numbers for supplying air to oil and gas fired furnaces. The pressure curve over a wide range of load is sufficiently flat to eliminate the necessity of adjusting burners as furnaces are cut in and out of service. The non-pulsating flow of air from the centrifugal compressor permits of close heat adjustment and the power required to compress the air is low because it is proportional to the actual air used, and also because the shaft efficiency of the machine is very high.

Recent foundry tests have shown that a centrifugal cupola blower operated at constant power input delivers a constant weight of air to the cupola, resulting in iron of uniform temperature being delivered to the ladles. This method of operation produces the desired results because the blower has a flat pressure curve, and the pressure variations in a cupola are small. While hand control is employed at present, there is being built an automatic constant weight air governor which will be controlled by the meter and adjusted for variation in atmospheric temperature and pressure will be automatic.

The positive pressure blower operating at constant speed has greater flexibility with respect to pressure range, but its volume is fixed and at constant pressure the power required remains constant, although the volume actually used may be reduced. At constant speed the pressure of a centrifugal compressor with a radial impeller is practically constant, but the volume may be varied in accordance with the demand and the power required varies approximately directly with the volume used. In most localities the range of atmospheric temperature throughout the year is about 100° F.; consequently, although the change in barometric pressure may be neglected, the oxygen content of one cubic foot of air varies 21½%, i.e., in order to deliver a constant weight of oxygen to the cupola 21½% more air must be provided on the hottest day as compared with that required when the temperature is zero. Therefore, if care is exercised in selecting a centrifugal compressor for this work, the proper volume of air may

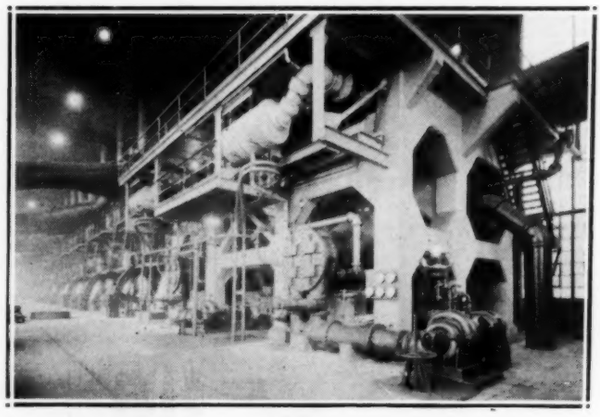

FIG. 7.

be provided for the cupola under all conditions and the blowing cost will be low because of low maintenance and high efficiency.

There are applications which can best be served by a turbine-driven compressor, such as blowers for blast furnaces, Bessemer converter blowers and coke oven exhausters, and standard turbines are employed in these cases. These turbines may be operated condensing, non-condensing, steam extraction or mixed pressure.

Foundry and forge blowers are usually driven by constant-speed induction motors, because the power

required to drive them is small and the pressure variation is slight, consequently the cost of variable-speed motors cannot usually be justified. Direct-current motors are also sometimes used for this service.

A motor-driven Bessemer blower of the centrifugal type should be driven by a variable-speed induction motor because the pressure requirements vary to some extent and by adjusting the speed of the compressor to give the required pressure the power saved will be material. A centrifugal compressor operating at constant speed and designed for 60° F. atmospheric temperature will develop higher pressure

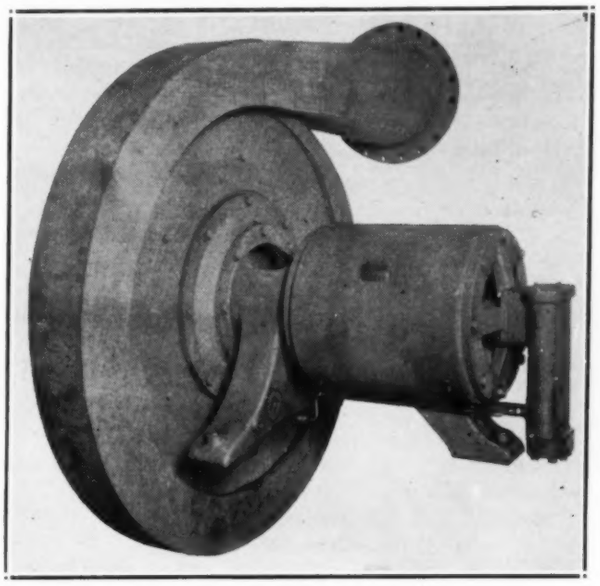

FIG. 8.

as the inlet temperature falls; the power required will also increase, and for this reason a synchronous motor should not usually be employed. Motor-driven gas boosters handling gas with variable density are affected in the same manner, and by installing variable-speed induction motors approximately as much power is saved as that used in the secondary resistance for speed and pressure control. This saving is partially offset by a slightly lower power factor, but the net result is in favor of variable-speed operation.

There are a few applications where pole-changing motors may be used for gas boosters, but their use is limited to very special applications.

Volumes and pressures are frequently specified which require, at available motor speeds, impellers of incorrect proportions. The solution in some instances is the use of a larger number of stages, but there are mechanical and cost limitations to this arrangement and it sometimes becomes necessary to increase the speed of the compressor through gears. There are a large number of geared compressors in operation, ranging up to 3500 h.p. Fig. 9 shows a 25 pound 8000 cu. ft. gas booster driven through gears by a General Electric steam turbine.

As stated above, the turbine-driven centrifugal compressor readily lends itself to various kinds of control mechanisms, such as constant volume governors, suction governors, pressure governors, etc., without introducing complicated mechanisms or reducing the efficiency. Similar devices may be provided with motor-driven compressors, but usually we must expect a lower efficiency, unless the initial cost of auxiliary apparatus can be justified by the saving in power resulting from its use. For instance, volume control may be applied to motor-driven blast furnaces blowers, but the manufacturers have not so far been able to obtain the full approval of steel mill executives of equipments which have been offered.

The volume governor is an important accessory to the blast furnace blower. This device automatically controls the speed of the unit in accordance with the demand for a constant volume of air required by the furnace.

The valve mechanism of a turbine-driven unit is controlled mainly by the constant volume governor, the speed governor being adjusted so that it comes into play at a point between the designated upper limit of the volume governor and the speed at which the overspeed governor is set to operate, thereby serving in the capacity of a pre-emergency governor only. The volume governor controls the speed of the unit in such a manner as to deliver that pressure to the furnace necessary to overcome the variable resistance offered by the furnace. The initial force for operating the valve mechanism is supplied by the pressure drop across an orifice located in the inlet pipe. This drop is proportional to the rate of air flow and any deviation in the rate of flow will change the orifice pressure difference which is relayed through levers, pilot valves, and pistons to the steam valves in such a manner as to develop the pressure necessary to restore the air flow to the desired rate.

Coke oven exhausters should be controlled in such a manner as to remove the gas from the oven at the rate it is generated. Battery governors are provided to maintain constant pressure on the ovens,

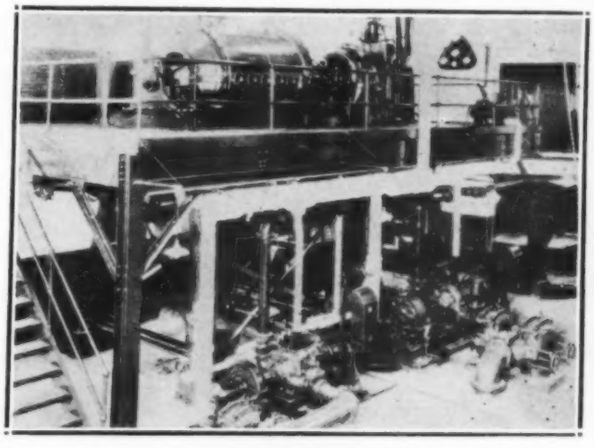

FIG. 9.

but they will not function properly unless the suction governors on the exhausters regulate the inlet pressure closely. The suction governor consists of a buoyant float connected to a pilot valve by means of a lever with knife edge connections. The position of the float is determined by the water in the tank and the suction on the pilot pipe of the governor. When the position of the pilot valve is changed due to changing the water level or a change in the inlet suction a port is opened or closed in the pilot valve cylinder of the suction governor, thereby changing the oil pressure under the piston in the turbine op-

erating cylinder. As the turbine operating piston moves up or down it changes the position of the knife edge fulcrum of the governor lever and restores the governor pilot valve to its normal position.

The governor may be adjusted to hold any suction up to 30 inches of water. This is accomplished by raising or lowering the water level in the tank and also by changing the position of the counterweight on the governor lever.

The turbine governor does not control the speed of the unit unless the suction governor calls for such a load that would bring the speed of the turbine

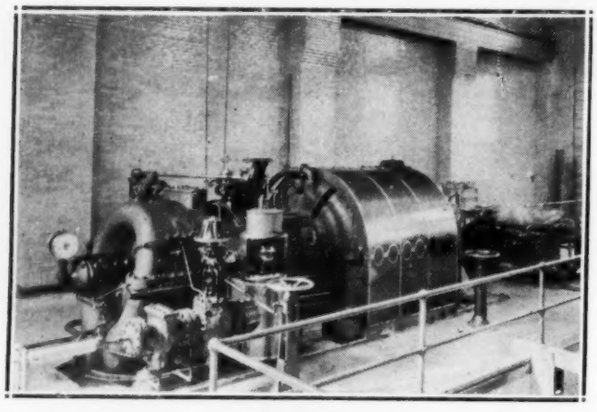

FIG. 10.

above its maximum value. In this case the centrifugal governor on the turbine will act and hold the unit at its maximum safe operating speed.

In addition to the applications for steel mills centrifugal compressors are used for agitation of liquids, as in ore separation and in ice manufacture, pneumatic handling of materials, scavenging and supercharging Diesel and gasoline engines, blowing water gas blowers, etc.

The Gillette Safety Razor plant in Boston has an interesting air compressor plant for the pneumatic handling of razor blades. Air at a vacuum of 21 inches mercury and at 35 lb. gauge pressure is supplied by centrifugal compressors. One unit operates as an exhauster and the other as a compressor, but they are interchangeable. The idea of exhausting to 21 inches vacuum with a centrifugal exhauster is novel and the turbine driving this unit is interesting in that it may be operated high-pressure condensing, high-pressure non-condensing, steam extraction, or low pressure. Fig. 10.

The development of superchargers for airplanes and racing cars has been very interesting. For instance, a supercharger for an airplane with 20,000-foot ceiling operates at 21,000 r.p.m. There are records of these machines being overspeeded 50% in service. At sea level this little compressor having but one stage will compress 1100 c.f.m. to 15 lb. gauge. It is driven by a 60-h.p. exhaust gas turbine and the compressor uses this power. However, the complete unit occupies not more than 2½ cu. ft. of space and weighs approximately 85 lb.

A turbine-driven supercharger designed for 30,000 r.p.m. has been tested to 80,000 r.p.m.

Another single-stage supercharger designed for 35,000 r.p.m., with an impeller approximately 10 inches in diameter, produces 40 lb. gauge pressure at sea level. The peripheral speed of the impeller and the air velocities are in excess of 1800 feet per second; the velocity of sound is only 1100 feet per second. The temperature of the gases delivered to the turbine wheel is 1300° F. At the time this machine was developed turbine experience was limited to approximately 700° F. steam temperature and wheel speeds of 900 feet per second.

Superchargers are now a standardized part of every modern airplane engine.

The application of the centrifugal compressor will be extended as the designer learns more of the problems involving its use and as engineers applying this machine become better acquainted with its characteristics.

Practically all racing cars are now equipped with superchargers and many of us expect to see this device standardized for pleasure cars.

The speed of compressors will be further increased and centrifugal compressors for higher pressures will become practical.

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*General Requirements For Safety**

BENZOL PLANTS

Construction and Safety

ONE of the greatest dangers to employees at a benzol plant is the result of inhaling poisonous gases; for this reason good ventilation is the most important consideration.

This should be accomplished by windows that can be opened and permanent ventilating openings along the louvers; also by ventilating openings along the floor line about every 25 feet in the distilling room—these openings through the wall should be not less than 6″ x 12″.

Forced ventilation has not generally been considered essential unless it be for the purpose of removing gases from special apparatus where employees are obliged to make repairs, or for removing fumes from agitator inspection pots.

Benzol buildings should not be designed with basements.

The distilling building should be provided with permanent louvers and of sufficient height that proper ventilation can be secured without recourse to forced ventilation.

Ventilation

1. The receiving tank into which the washed benzol is drawn should be ventilated to the outside of the building.

*Prepared by The Committee of Safety, United States Steel Corporation.

2. The waste-soda lines should be ventilated; the ventilator being supplied with steam-jet suction.

3. All pipe trenches should be made sufficiently deep that the pipes can be supported on cross angles embedded in side walls in a way that allows a clear, unobstructed opening at least 6 inches below the supporting angles for the entire length of the pit, to enable effective flushing of the pit.

4. To prevent free exchange of air in the vent lines leading to points outside the building, a fine-mesh gauze should be placed at a convenient place close to the end of the pipe where it is readily accessible for cleaning and inspection.

Fire Dangers

5. Motors should not be used in the benzol distilling rooms or near agitators. Oil-circulating tanks should not be located below pump room.

6. Electric wires should all be in conduits and all lights should be provided with vapor-proof globes. Fuses and switches should be either in the circulating pump room or on the outside of the distilling room.

The use of extension cords should not be made unless absolutely necessary, and then removed as soon as repairs have been made.

7. If the circulating oil pumps are driven by electric motors, the pump house should be located outside or separated from the distilling room by tight brick walls, and not located over oil-compartment tanks.

8. A 2-inch steam line with close perforations, running close to the floor, should be laid along the entire building. This line should be perforated with about ⅛-inch holes and connected to one or more valves located on the outside of the building, readily accessible, to be used in case of fire.

Benzol Tanks Storage-Receiving-Hot Oil-Draining-Agitator

9. All storage tanks should be of steel construction with air tight steel covers.

All openings for filling, venting, measuring, sampling, etc., should be protected by a double concentric screen so arranged they will not be removed during these operations. They should be so constructed that they will prevent flames entering the tank, prevent loss through evaporation, and provide against a vacuum when pumping out.

Each tank should be supplied with a vent, taking care of slight temperature changes, thereby preventing the accumulation of fumes in the building. Venting and relief areas should be sufficient to relieve sudden pressure in the tank due to unusual causes, such as fires. These areas will vary in size with the tank capacity; 100,000 gallon tanks and over should have at least one 6-inch vent line and one 6-inch emergency relief opening, while the 10,000 gallon tanks should have one 2-inch vent line and one 3-inch relief opening.

Measuring, sampling, etc., should be done through the relief opening.

The removal of manhole covers for measuring, sampling, or other purposes is dangerous because of static or other sparks.

Barrel-filling equipment should be provided with a double concentric screen for barrel openings, and permanent screen cylinders for filler-line nozzle.

Tank car filling equipment should consist of double concentric screen protection for the tank openings, and permanent screen cylinders for filler-line nozzle.

10. Sewer connections from benzol plants should all be trapped at building entrances, and in addition an intercepting sewer should be built with ventilated manhole before benzol sewer water is allowed to enter main sewer lines.

11. Napthalene pans should be set in the open and located a safe distance from locomotive cinders or fires.

12. Locomotives passing around the benzol plant should all be provided with spark arresters, or all windows, doors and other openings exposed to locomotive sparks should be covered with a fine mesh screen.

13. The agitators should be housed in a separate building, close to the acid regenerating pots. At least 2 stairways or other means of escape should be provided from the operating floor of the agitator building.

14. The elevation of the agitators should not be higher than will be sufficient to drain the acid sludge by gravity to the acid regenerating pots.

15. The circulating oil tanks preferably located in the base of the oil scrubbers, to minimize explosion dangers.

16. The railroad tracks should be located as far from the benzol plant as the lay of the land will possibly permit.

17. Intercepting sewers should be built between the benzol sewers and the main sewers to prevent the accumulated gases from traveling along and filling up the manholes.

18. The stills should be supplied with platforms around dephlegmators for easy inspection of leaks, and stairways should be provided on each end of the platform.

19. Acid and soda tanks should be of large design and located outside the agitator building. Acid and soda solutions can then be drawn by gravity to small measuring tanks in the agitator room. These measuring tanks should not be located directly above the agitators, but to one side, so that spillages will not be dangerous to the operators working around the agitators.

20. The benzol laboratory should not be located closer than 75 feet from any part of the benzol distilling operations.

21. Fire water plugs, chemical tanks, hose, house and approved fire extinguishers should be conveniently located in and about the plant, as well as the perforated steam line in the benzol building.

22. The pit containing horizontal tanks of finished products should be equipped with steam lines for extinguishing fires and water lines for steaming and washing these pits. They should also have artificial ventilation.

23. A well-ventilated roof should be built over the horizontal tanks to protect same from the sun in the summer-time.

24. A water spray should, during summer months, be put on storage tanks containing finished forerunnings, to reduce the escaping of volatile vapors.

25. All outside benzol storage tanks should be located at a distance sufficiently far apart so that in

case of leakage the entire contents of the full tank will remain confined within an embankment or other retainer. These storage tanks should all be equipped with steam for smothering fires.

TANK CARS

Tank Cars should be equipped with platforms around the domes for the safety of workmen.

The safety platform should extend, on each side of the dome lengthwise with the car, sufficiently to give ample working space, but the width of the platform should be as narrow as practicable, approximately the same width as the dome.

Railings should be placed on these platforms, but in no case should they be higher than the highest point of the dome.

Platforms, planks and ladders should be carried on their own supports. There should be no riveting through the tank shell.

Note: The limitation as to width of platform and height of railings is made so as not to interfere with the passage of cars through certain railroad tunnels.

BESSEMER DEPARTMENT

Pig Iron Yard

1. Suitable provisions by screens or otherwise should be made to protect men from flying pieces of pig iron, when cars are being unloaded.

2. There should be division walls in piles of pig iron, to prevent iron from tangling and making dangerous piles; also to protect stocker from flying pieces of pig iron when car is being unloaded in other bins.

Cupolas

3. Cupolas should be covered at charging floor when liners are working in cupolas, to prevent chargers throwing material into cupola or brick falling from stacks on men. These covers should be made of heavy wire screen or net, to allow ventilation to men working in cupolas.

4. Section of cupola just below charging floor should be made of cast steel, so that it will not warp and allow scrap and other material to fall between cupola and charging floor.

5. Drop chutes should be enclosed as nearly as possible, a 4-inch hole being ample to place bar for knocking out props. Where practicable, the props should be pulled by means of snatch block, cable, or locomotive, rather than by hand.

6. When cupola cinder is run through floor, this hole should be provided with a shield of sufficient height to prevent workmen from stepping into hole.

Mixers

7. Mixers should be counterbalanced so that if pressure is off tipping cylinder the mixer will return automatically to an upright position. In order to make sure that counterweights will bring mixer to an upright position and not be held by water in cylinder, a cut-off valve should be placed next to the operating valve on pressure pipe to front of tipping cylinder, which valve will cut off the pressure from cylinder and open it to the discharge.

This valve is to be used only in case of emergency.

8. Hydraulic cylinder under mixer should be protected by steel plate, covered with fire brick.

9. A warning signal should be installed, to be rung by pourer before pouring a heat.

10. A safe means of escape should be provided for men working on mixer platform.

11. The auxiliary hoist of ladle crane should be equipped with a counterbalanced hook which can be attached by the craneman after the ladle has been hoisted to the pouring position.

12. Where knuckle-jointed arm is used for dumping iron ladle, protruding bolts and nuts should be covered with leather or other material as a guard.

13. Where plunger elevators are used for hoisting metal to mixer elevation, the hoist should be equipped with safety dogs. The opening in the floor caused by raising the hoist should be protected.

14. Automatic rail stops should be placed on either side of opening of hoists conveying iron to mixers.

15. All cages on hot-metal cranes should be arranged so as to give ample protection to cranemen in case of the spilling of a ladle of hot metal. Each crane should have a sheet-iron closet lined with asbestos or other effective means of escape to be used by cranemen in case anything goes wrong with machinery when hoisting hot metal.

16. Guards should be placed in front of truck wheels and an automatic alarm should be installed on mixer iron transfer ladle.

17. There should be a signal system between mixer pourer and operator of transfer ladle to notify operator when heat is poured and ladle is ready to move.

Vessels

18. A warning signal should be provided to give warning when vessel is to be tipped.

19. A system should be installed for warning men working around vessels when scrap is to be charged in the vessel.

20. When new vessels are being installed, or when making repairs or replacements that would justify the cost, vertical outside packed plungers are recommended, thereby doing away with inside packing.

Steel Pouring Cranes

21. Safety catches or stops should be placed on jibs of all steel cranes to prevent ladle running off the end of jib.

22. Steel cranes should be equippel with automatic safety device that will hold crane jib and ladle suspended over molds regardless of failure of pressure.

Ladles

23. All ladle trunnions should be drilled and tested before being placed in service.

24. All ladles should be bottom-heavy and so constructed that when locks are out of place ladle will not upset.

Pouring Platform

25. We believe that a side lever for pouring steel is much safer for the men than pouring from straight in front of the ladles.

26. Pouring platform should be amply large and provided with a number of exits to allow men to escape in case of accident.

27. All platforms for operators should be so placed that operators can see the operation of their machinery at all times.

28. The uncapping stand should be equipped with sliding doors or railed off to a distance that will allow the proper cooling of ingots before they can be uncapped.

BLAST FURNACES

1. Telephone or Speaking-tube should be provided at each blast furnace, between the skip hoist operator's house and the stove-tender's shanty. This installation should also include a connection to the furnace top for use of signalmen or men engaged in constructing or repairing top of furnace.

2. Preventing Gas Getting Back Into Engines: Mixing pipes should be equipped with automatic valves of the Lorain or some similar type.

3. Preventing Stalling of Engines: Two automatic relief valves should be installed on the cold-blast mains set at a predetermined pressure to safeguard the blowing engines. It is recommended that one valve be installed near the engine and one near the snort valve. These valves should be of sufficient size to prevent stalling of engine in case both stoves are shut against the furnace.

4. Preventing Explosions or Fires in Dust-catchers and Cold-blast Mains: Not less than a 3-inch steam connection taken from a 6-inch steam line is recommended for both the dust-catchers and cold-blast mains. It is also recommended that there be two valves in the steam connection to the cold-blast pipes—one closing it against air pressure and the other against steam pressure, with a drip cock between these valves to be left open, to detect leaks and prevent leakage of steam into the blast. Two steam connections are recommended for the cold-blast pipes—one near the snort valve at the stoves and the other one near the engines.

5. The cause of the fires in cold blast mains has been laid to poor grade of oil, an excessive amount of oil, failure to clean out pipe at frequent intervals, and missing valves.

New blowing equipment should be such as will require a minimum amount of lubricating oil at the air tubs.

Air tubs should be equipped with automatic discharge valves or with check valves which will prevent reversal of air flow.

Ample air receiver capacity should be provided for at engines.

Oil drains should be placed at all low points in blast conduits.

6. A Dust-catcher Dumping Device should be provided, which will permit its being dumped from a sufficient distance to avoid possible burning of operator. The down legs should be low enough to prevent scattering of the dust.

7. Sprinklers should be installed sufficient to wet the dust thoroughly as it is emptied into cars.

8. Gas-cleaning Systems: Every care should be taken to remove, so far as possible, the necessity for men coming into contact with gas. All cleaning and repairs inside of washers or dryers during a furnace campaign should be eliminated so far as practicable. Particular attention should be given to the design of the bottom of the washer where the waste water is discharged, with the view of preventing clogging, either by discharging the bulk of water through a syphon pipe forming a gas seal and providing a separate drain at the lowest point of the seal, or by some equally efficient means, which will prevent an accumulation at the point where the sediment usually builds up.

9. The water seal should be placed as near the furnace as possible—not more than one dust-catcher intervening between the water seal and the furnace.

10. Particular attention should also be given to the design of the gas-inlet connections with reference to minimizing the possibility of accumulations of flue dust forming at this point, and with a view of providing facilities for safely and easily removing such accumulations.

11. All gas-cleaning and washing plants should have, in addition to the water seal ahead of the washer, means for sealing the gas at the opposite end of the washer system.

12. In addition to the gas valves mentioned above, the main gas leads should be designed in sections covering groups of not more than two furnaces, and valves should be provided for sealing off these sections at both ends. These mains should be provided with a sufficient number of flush valves so that mains may be readily washed out from the outside during operations.

13. A sufficient number of manholes should be provided in all gas mains for ventilation and ready access, amply large to admit the passage of an average-size man.

14. Breathing apparatus, preferably of the self-contained type, should be provided for the use of men working in gaseous areas.

15. Ventilation for Theisen Washer Buildings: Careful consideration should be given to the proper ventilation of the washer building. It is suggested that the supervising instruments be installed in a separate room sealed gas-tight against the washer room, and that at no time should a man be allowed to remain alone within the washer room proper.

16. Explosion Valves on Bleeders, Gas Mains and Dust-catchers: Explosion valves which will prevent the throwing out of heavy material during slips should be placed on all bleeder pipes. The Baer valve is recommended for this purpose. Dust-catchers and gas conduits should be equipped with explosion valves wherever there is danger of pockets of gas forming, so that when steam is turned on the gas can be driven out through these openings. Where conditions require it, these explosions valves should be placed on bleeder stacks.

17. Mufflers: Blow-off valves should be muffled so as to deaden the noise; it is suggested that in some installations this may be accomplished by connecting the blow-off to the chimney-flue.

18. Platforms, properly railed and with toe-boards, should be installed at all elevated points where employees are required to go to perform their duties, including the outriggers on the top of furnace, steam or air cylinders for the bells, and the explosion valves.

19. Bustle Pipes should be equipped with a railed walk and toe-boards.

20. All Stairs or Ladders to Bustle Pipes or Platforms Around the Blast-furnace Shell should be

equipped with a warning device so attached to a gate that it will sound a warning when these stairs or ladders are used. A tripping device so connected to this apparatus that closing the gate will not stop the warning signal is an added safety feature.

21. Tuyere Eyesights of an approved type should be installed.

Tuyere Cooler Castings should be so designed that they may be anchored to prevent an explosion blowing them out. One method is to cast lugs on the cooler which will accommodate an "L" shaped pin.

22. Mud Guns should be equipped with a funnel shaped casting over the receiving hole of the mud cylinder and the exhaust should be muffled or piped to the sewer.

23. Casting Holes, where ladles are loaded under the floor, should be grated or railed.

24. Runways or Stairs, amply wide to allow quick escape, should be provided at the ends or sides of cast houses.

25. Elevated Floors of cast houses should be properly railed.

26. Cinder Notches should be provided with shields to protect men working there.

Mechanical cinder notch stoppers operated from a safe distance are recommended.

27. Gates in Iron and Cinder Runners should be operated from such a distance that the danger of burning operator will be eliminated.

28. Hot-blast Stoves serving the same group of furnaces should be connected by railed walks, built with solid bottom and toe-boards at least 12 inches high.

29. Protection from Slips: A steel roof should cover all points where men work around a blast furnace. The sheeting on the sides of the cast houses should be carried down far enough to prevent storms beating in or stock being thrown in by slips of other furnaces, and hoisting machinery, cranes, etc., near a blast furnace should be roofed to protect the men.

30. A small house should be provided on top of a furnace or runway by a furnace, to protect men from slips.

BLOWING-ENGINE HOUSE

1. Signal Whistles in Blowing-engine Room should be blown by electric power, operated by switches in cast house, and means provided, if necessary, at the switch, to show when circuit is made.

2. Signal Lights visible to the engineers, which will show the number of the furnace signaling, should be installed in the engine room, to avoid mistaking the sound of similar whistles.

STOCK YARDS AND STOCK BINS

1. Ore-bridge Trolley Cabs should be equipped with brakes, air whistles or gongs, and with SAFETY SWITCHES located on top of cab.

2. Ore Bridges should have SAFETY SWITCHES located at the trucks which will enable an employee working on them to cut off all power.

3. Ore Bridge Trucks should be provided with automatic brakes and with such other necessary electrical or mechanical devices as will control the movement of the bridge during severe wind storms.

4. All Controlling Mechanism of Bridge Movements should be located in the cage.

5. Flue-Dust Bins should be provided with heavy cast-iron knife-edge sluice gates adapted to cutting off hot dust.

6. Pockets of All Kinds should be so shielded as to prevent material, dumped from above, running through the pocket and injuring employees below.

7. Scale and Transfer Cars should be equipped with air-brakes, fenders, and gongs which ring continuously while the car is moving.

8. Skip Pits should be so constructed that there will be ample clearance for a man on all sides of the skip car. All skip pits which can not be entered at bottom level should be equipped with stairs. Where openings are made in stock trestle to accommodate skip, they should be guarded.

9. Skip Track should be equipped with a shield at points within 7 feet of ground level where workman may place hand on rail.

10. Skip Track should have a shield on under side from top of furnace, terminating in a chute near the base of the skip.

BOILER PLANTS

(Approved by Board of Engineers)

1. Conformity With Local Ordinances: The legal requirements of the community in which the boilers will operate are, of course, to be observed, as they are devised with safety provisions in view. If there is any direct conflict between such ordinances and the following suggestions, the ordinance will, of course, take precedence.

2. Factor of Safety: Unless otherwise specified (for instance, by local ordinance), all parts of the boiler which are used under steam pressure shall be designed with a factor of safety of not less than 5. By this it is to be understood that with a material which ruptures when a stress of 60,000 pounds per square inch is applied, the maximum stress to which this material is to be subjected when in service as a part of boiler must not exceed 12,000 pounds per square inch.

3. Longitudinal Seams of Cylindrical Shells: All longitudinal seams, steam and water drums should be butt strap joints of approved type and so arranged that the gases will not be impinged upon them. Rolled steel flanged nozzle connections for steam outlets should be used. Where tube headers are used as in some types of water-tube boilers, they should be so designed that resistance to pressure on cap will not depend on the holding power of the cap bolt. All tubing should be of steel.

4. Rivet Holes in Plates: All rivet holes shall be drilled with the sheets bolted in place, then the plates moved apart and the burr on the edge of the holes removed. In case the exigencies of the construction work require that a few holes be punched, they should be punched at least ¼ inch smaller than the size of the rivet and increased to full size by the use of a reamer. The proper making of rivet holes in boiler plates is regarded as of special importance, and the purchaser should always reserve the right to have an inspector present while this work is being done.

5. Drum Heads: The heads of cylindrical shells or drums should be pressed and not rolled or hammered.

6. Connections for Pipes: One-inch or under pipe connections to boiler shells, except those for

water columns (see paragraph 22), may be connected to the shell plates by threads cut into the plate. All pipe connections larger than 1 inch should be by means of pressed or rolled steel flanges or annealed steel castings riveted to the plates, or by other approved means.

7. Manholes: Manholes in tube or drum should be reinforced by steel rings having a sectional area equal to that of the piece removed in forming the opening, measured on its longest axis.

8. Manhole Covers: Manhole covers should be made of flanged steel or annealed cast steel.

9. Cast Iron: No cast iron shall be used in any part of a boiler subject to pressure. If castings can not be avoided, they should be annealed steel.

10. Fastening Tubes: In water-tube boilers the tubes should be rolled and belled, extending not to exceed ⅛ inch into the water space. In fire-tube boilers the tubes should be rolled and beaded.

11. Boiler Supports: Boiler supports are to be made of structural steel in all cases where the boiler is not self-supporting on the foundation. The supports for water-tube boilers should be independent of the brickwork of the setting, so far as the movements of either boiler or setting due to heating are concerned.

Where two horizontal water-tube boilers are set together in one battery, continuous girders should run over the boilers from one side of the battery to the other, from which the boilers are to be suspended. These girders should be strong enough to carry the boilers without vertical columns set in the division wall between the boilers. Cast-iron brackets on boiler shells should not be used.

12. Stays for Boiler Settings: The stays of the settings should not be located where they are subjected to a temperature of over 600° F. This result may be secured by observing the suggestions under paragraph 11.

13. Dry Plates: A dry plate should be placed in the drum under the steam nozzle of each boiler, attached by angle-irons, riveted to the interior of the steam drum or boiler shell. This dry plate should extend about 3 feet on each side of the steam nozzle, and it should be about 8 inches from the top of the shell. Steam on its way to the steam nozzle passes around the ends of this dry plate. If dry pipes seem to be more suitable in certain types of boilers or under certain conditions, they may be used instead of dry plates.

14. Steam Mains and Connections Thereto: Steam headers receiving the steam from several boilers should be placed at a sufficient distance from the nozzles of the boilers to permit the use of "gooseneck" connections capable of considerable expansion without introducing dangerous stresses on flanges or nozzles. A straight connection from the boiler nozzle to the steam header should be avoided. "Gooseneck" connections to the side of a header may be used, but the top connection (that is, vertical connection on header) is preferred. The bottom connection to a header is an objectional construction, and should not be used. Where a line reduces from one size to another, eccentric fittings should be used in order to bring the bottom of the different sizes of pipe to the same grade line, and thus avoid pockets.

15. Pipe Flanges:

(a) Pressed or rolled steel flanges are preferred, but cast steel may be used where the conditions make it seem advisable; and cast iron may also be used for moderate pressure and small sizes. Sections of pipe thus fitted should not be bolted in place until the companion faces of the flanges are machined true planes and parallel. Flanges should match properly without the necessity of springing the pipe into place. If the pipe section does not fit into the system properly, as a matter of safety, to secure the necessary alteration of form, fit the section and flanges to a prepared templet.

(b) It is not necessary to corrugate the faces of the flanges. Corrugated metallic gaskets have proved satisfactory, of steel, monel metal or copper, the preference being in the order named. Where there is water in the steam, asbestos gaskets or corrugated copper with asbestos between have not proven satisfactory. Under these conditions rubber will give better results than asbestos.

16. Gate Stop Valves: A gate stop valve of approved construction should be set at the outer extremity of the "gooseneck" connection to the boiler and as near the steam header as possible. In all cases the valve stem should have its threads outside of the valve casing.

17. Non-return Valves: Non-return valves are advised for all boilers, the same being set as near to the boiler as practicable. It is also considered advisable to provide quick closing valves at suitable locations in the main steam lines, which will permit an injured line to be shut off immediately.

18. Drain Pipes: Drain pipes should be connected to the several "goosenecks" just above both stop and non-return valves, to prevent pocketing of water when valve is shut, said drain pipes leading to receivers of traps for the automatic removal of water that may collect. The outlets from these drain pipes should be so placed in receivers or traps that water can not return through these pipes. A check valve should be set in each drain pipe, to prevent the backward flow of steam when the boiler is out of service.

19. Spring-loaded Pop Safety Valves:

(a) At least two spring-loaded pop safety valves should be applied to each boiler by means of a separate steam nozzle having no connection or possible communication with any part of the steam system. The casing surrounding the safety-valve spring must be locked in such a manner that only authorized persons may have access to the spring for inspection or adjustment. A testing lever should project through the casing, whereby the hand lifting of the valve from its seat is possible at the time of its periodic inspection.

(b) Each boiler should be fitted with sufficient safety-valve capacity to discharge all the steam the boiler will produce when it is evaporating at the capacity at which the boiler normally operates.

(c) In purchasing safety valves the manufacturers should furnish reliable information as to the number of pounds of steam the valve will discharge per hour, as this varies widely among the different makes of valves of the same diameter.

(d) The springs of safety valves become gradually weaker with use. In order to make a weakened spring continue to resist the pressure, it must be

more compressed, which reduces the pitch of the spring and the lift of the valve. Therefore a record should be kept of the lift of the valve at its rated capacity, and all valves gone over at least once per year, to be sure that approximately the original lift is still obtained.

(e) All safety valves on boilers in regular service should be tried at least once during each turn by easing them gently from their seats to insure the valve always being free to operate.

(f) Escape pipes from safety valves should be vertical and have an outlet through the roof of the boiler house wherever practicable. Horizontal escape pipes from safety valves are to be avoided in all cases, as they produce an undesirable and frequently severe thrust on the boiler nozzle when a violent escape of steam occurs.

(g) Drain pipes should attach to escape pipes from safety valves as near as possible to the safety valve. These drains should be open connections to ash-pit or sewer.

20. Steam-pipe Expansion: Systems of steam piping should be laid out with great care, in order to provide for expansion and contraction. The expansion should preferably be taken care of by loops or bends, and if necessary by expansion joints. In all cases the anchorage of the piping is just as important as the loops or bends. The pipe systems should be anchored at certain points in such a way that these points will be absolutely fixed.

It is particularly necessary to see that this expansion does not throw any undue strain on any part of the piping system or on the steam chests of engine cylinders, etc., to which the pipes are connected.

21. Blow-off Pipes:

(a) When the blow-off branch pipes are so located as to be exposed to the hot products of combustion they should be protected by fire-brick piers. A sufficient space for the inspection of all parts of the blow-off connection should be provided, and the contact of same with brickwork, flue dust or other moisture-collecting material is to be avoided.

(b) Blow-off valves should be attached in pairs to each blow-off pipe; the valve next to the boiler being a gate valve or straightway cock; the one connecting the branch to the main blow-off line should be a regular boiler blow-off valve. A short drain pipe attached to the portion of blow-off branch between these valves is suggested, but not imperative.

(c) Blow-off headers should be laid in a concrete trench with Y connections to the branches. Steel pipe should be used, and the pipe should be free to expand, to prevent excessive strain when it becomes heated.

(d) Blow-off headers should discharge into a hot well provided for the purpose, and not directly into a sewer. This hot well should be provided with a pipe at least ten feet high for the escape of vapors.

22. Gauge Glasses, Water Columns, Etc.:

(a) Each boiler should be equipped with a water column and fittings in the manner hereafter described, and so located that a view of the gauge glass from the boiler-room floor is not intercepted by stairways, platforms, etc. Where it is necessary to provide a special platform for the water tender, this platform should not interfere with a view of the gauge glass from a position on the boiler-room floor, because it may be necessary to verify the water level from this point.

(b) The water columns should be of approved design and each fitted with not less than three try-cocks, with angle cocks and swivel guard of the revolving shield or wire-netting type for the gauge glass. This gauge-glass guard is to be capable of rotation around the glass as a safety precaution while work is being done upon the water columns, such as the insertion of new glasses, packing the same, etc.

(c) The try-cocks on the water columns are to be three in number, of the lever type exclusively, and connected by chains or rods to handles readily accessible from the boiler-room floor and operating platform.

(d) No valves are to be permitted between the water column and the boiler, and the pipe connection of the water column to the boiler shell should be by means of steel flanges riveted to the shells, as tapped connections in boiler plates for the purpose intended.

(e) In steam and water connections to water columns, no ells are to be used; crosses and plugs should be used, which will give ready access for internal cleaning of all parts of the water column system.

(f) Water columns in horizontal tubular boilers should be set so that the difference of level of the bottom try-cock and that of the level of the top row of tubes is not less than 3 inches. Gauge glasses should be so set that the lowest visible level of water in said glass will correspond to 1½-inch level of water over the tubes.

(g) Drain connections from the water columns should have an open end into the ash-pit and be of sufficient size to permit any foreign material that may enter the columns to be blown out.

(h) Metallic unions of the "Kewanee" type, obviating the use of any soft packing material, should be used.

(i) Pipe connections leading to the water columns should be covered.

(j) Each water column should be equipped with a high and low water alarm whistle.

23. Feed Pipes:

(a) Each boiler feed pipe should be fitted with the following valves:

(1) A stop valve near the main feed line if the boiler is one of a battery, or near the feed pump in case of an isolated boiler.

(2) A feed controlling or regulating valve of approved type. (See further recommendations regarding feed control.)

(3) A suitable form of check valve, closing with any backward movement of the water from the boiler.

(4) A suitable strong valve with rising stem between the check valve and the boiler.

(b) The feed pipe should deliver the water very considerably below the lowest water level of the boiler. The feed water should be discharged in such a place in the drum that it does not come in immediate contact with drum sheets exposed to high furnace temperature.

(c) A drain pipe should be provided between valve at main feed line and stop valve at boiler, to

prevent building up water pressure, should the former valve leak when the boiler is out of service.

24. Feed Pumps:

(a) Each boiler plant consisting of more than one boiler should be provided with feed pumps in duplicate. If direct-acting pumps are used, these should preferably be of the outside packed plunger type. For a single boiler the feeding device may consist of one steam pump and one steam injector, or of two steam injectors.

(b) Feed pumps should be so located with reference to the lowest level of water in feed-water heaters that there will be sufficient head on the inlet valves of pumps at all times to overcome the frictional resistance of the valves, to provide the necessary velocity of flow to the pump and to overcome the vapor pressure due to the temperature of feed water in the pump chambers.

(c) Valves for feed pumps should be either metallic valves or a type of hard rubber or fibre capable of withstanding disintegration under the high temperatures which will exist.

(d) Where economizers are used, the feed-pipe system should be protected by a relief valve, possibly assisted by an air chamber to protect economizers and feed piping from excessive pressure or shocks.

(e) It is advisable to equip the feed pumps with governors which will maintain a pressure in the feed pipe a constant number of pounds above the steam pressure. These pump governors are known as "constant excess governors."

(f) Where it is at all possible, there should be two sources of water supply to feed-water pumps. In many plants this is possible by connecting up with a city water line or by connecting to the regular service system of the works when the heater is ordinarily supplied with hot well water by an independent pump.

25. Feedwater Heaters:

(a) The overflow pipe and the steam escape pipe should be of ample size, and so located that they will always be free and unobstructed.

(b) If a balanced valve is ever used in the steam escape pipe to divert part of the steam to a heating system, its use should be attended with the greatest care and only by an experienced engineer. Under these conditions it is advisable to have the heater equipped with a mercury column or, preferably, a low-pressure recording gauge, so that the pressure maintained in the heater by the balanced valve will always be known.

(c) Every effort should be made to prevent lubricating oil entering boilers with feed water. Especial care should be used in plants with surface condensers, cooling towers and return tubular boilers.

26. Feed-water Regulators:

(a) The use of feed-water regulators is recommended wherever they will be of advantage or assistance to the water tender in maintaining the water level. Their use is not suggested for the purpose of fuel economy nor to effect labor saving by dispensing with water tenders, but only for the purpose of supplementing the work of the water tender, to relieve him of the detail of valve manipulation, thus enabling him to give closer supervision to the maintenance of the proper water level in all boilers.

(b) Wherever water regulators are used, they should preferably be accompanied by the use of governors on the boiler feed pumps, the constant excess governor mentioned above being preferred.

27. Damper Regulators: Where damper regulators and non-return valves are both used, great care must be exercised in locating the steam connection of the regulator to the main steam system. If this steam connection is made in the main steam system, and a break occurs in this system, the steam pressure will fall, closing the non-return valves and also opening the damper regulator, thus putting full draft on boilers with the main valves closed. To avoid this, the connection for the damper regulator should be made to several boilers between non-return valves and boilers.

28. Steam Gauges:

(a) Each boiler should have its own steam gauge, attached by means of a syphon of sufficient capacity to insure the gauge tubes being kept full of water.

(b) At least one recording gauge should be connected to each steam system, so that should an accident occur there will always be available a record of the steam pressure at that time.

(c) All steam gauges should be kept in good condition, so that the pressure indicated will be approximately correct. For testing gauges, a weight-testing machine should be used, and such a machine should be available for the use of each Works where boilers are operated.

29. Settings of Boilers.

(a) Settings of boilers should be constructed with full consideration of the requirements in paragraph 11 on supports, so that the boiler structure is independent of the brickwork, so far as possible.

(b) Paragraph 12, referring to stays for settings, should be kept in view when designing new settings.

(c) It is particularly important in the case of boilers having large bottom drums, such as those of the Stirling type, to keep the brickwork around the windows at the ends of those drums entirely free from contact with the metal surface. Those windows should be closed by a separate tight-fitting cast-iron door, attached to a circular casting, which is properly fitted into the brickwork.

(d) Communicating with the last pass in gas-fired boilers, it is advisable to have one or more explosion doors fitted into the wall of the setting, the seats of which doors should be set at an angle at which the gravity closure of the doors is obtainable, while they are at the same time free to open in case of excessive pressure developing in the settings.

(e) Boiler fronts should always be bolted to the settings in such a way that they will not become loose or fall down when the brickwork is removed.

30. Platforms, Stairways and Lighting:

(a) A system of walks or runways should be erected to give convenient access to overhead valves, water columns, etc., also walks from boiler to boiler, and suitable platforms at individual valves, from which they can be safely operated or repaired.

(b) Walks and platforms should be well lighted and free from breaks or obstructions which might interfere with their use.

(c) They should be equipped with hand rails not less than 36 inches high, with two horizontal members, and with toe-guards not less than 4 inches high.

(d) Walks and stairways should be of suitable steel construction, checkered steel plate or grids being used for flooring except in the vicinity of water columns, where it may be advisable always to have the gridiron construction, in order to provide a clear view of the water column from the boiler-room, as previously recommended.

(e) Wherever possible, railed stairways are to be used in preference to ladders. Where practicable, stairways should be substituted for existing ladders.

(f) Means of access should be provided for overhead walks at both ends of each line of boilers, and in large plants one or two intermediate stairways are desirable.

(g) It is very desirable to have red incandescent lamps suspended near important cut-off valves or branches from steam mains or headers, to facilitate readily locating same in case of emergency.

(h) A protected light, preferably an incandescent lamp, should be suspended near each water column.

(i) Special attention should be given to securing good illumination throughout the boiler house. Unless the illumination is exceptionally good, it is advisable to have at least one light at each of the stairways leading to overhead platforms, particularly at the upper end of the main stairways.

31. Numbering Boilers:

(a) Each boiler should be fitted with at least three number plates (each having the same number), as follows:

(b) One on the front of the boiler; one on the rear of the boiler; one on the pipe system between the boiler steam nozzle and the header, in such a position that it can be readily seen from the walk or platform on the top of the boiler setting.

(c) These plates may be enameled, with the figures of a different color, or heavy sheet metal with perforated figures.

32. Stokers, Coal- and Ash-handling Machinery:

(a) All gearing for stokers, coal- and ash-handling machinery, etc., should be as completely covered as possible by substantial cast-iron or sheet-metal covers so designed as to be readily detachable.

(b) All couplings, set screws, keys, bolts, etc., in moving parts must be covered or countersunk in such a way as to eliminate danger of accident. Unused portions of keyways should be filled, so as to present a smooth surface.

CHARGING CARS

1. Charging cars should be equipped with guards over the truck wheels, covering both the front and the sides of the wheels.

2. Warning signals should be placed on all cars.

3. All gears should be encased, and a plate guard should extend along both sides of the traversing carriage runway, of sufficient height (at least three inches) to prevent men placing their feet on the track.

4. Bumpers should be placed on each traversing carriage track, to prevent the carriage running back closer than two inches to the end plate.

5. Open type controllers should have asbestos lined steel guards over the movable contact parts.

COAL-CRUSHING AND COAL-PULVERIZING

1. No open lights should be allowed, nor men be permitted to use matches or to smoke on these premises.

2. Incandescent electric lamps when used should have wires carefully insulated to prevent short-circuiting, and the bulbs should be protected by wire cages or vapor-proof globes, or both. The switch for controlling lamps should be enclosed and should be located at a point where there is little or no dust. Such switch should preferably be in a locked box.

3. Electric motors should be dust- and flash-proof when located where there may be a cloud of dust.

4. The elevators should be enclosed with a tight covering, preferably of sheet steel rather than wood. If desirable to close shaft all the way, an opening should be left at the top or an explosion door provided to relieve pressure in case of explosion.

5. As few places as possible where dust can lodge should be allowed. This may be accomplished by covering ledges and projections with sheet metal or cement at such a steep angle that dust can not pile up on them.

6. Heat for employees, if provided, should be by steam or hot-water radiators. Open stoves should not be used.

7. A steam jet may be used to advantage when there are large volumes of dust arising.

COUNTERWEIGHTS

All counterweights should be so situated or guarded that they can not fall on workman should something break.

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*Discussion: Electric Heat Committee Report**

Foundry Practice

C. S. Proudfoot†: With single voltage for foundry practice, what is the proper voltage to use?

G. Mills§: The proper voltage for foundry operation depends on the design of the furnace, diameter of the furnace and height of arch. At the present time, those sizes are fairly well standardized; the voltages in use ranging from 220 down to a minimum of 175 on the newer furnaces. There are still a number of the older installations operating at low voltages. Recently a number of these old installations have been revamped and are using higher voltages up to about 190 volts. The point brought out on the possible use in the foundry is simply brought out largely to get an expression from the Association. Of course, dual voltages means more expensive transformers, more expensive switch equipment, and in probably 90 percent of the foundry operations, the low voltage is not used because it is simply a protection proposition. A good operator,

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using selected scrap, can bring his heat to the right analysis when his temperature is right and he pours the bath. The thought is that 15 percent of the total cost of the installation represented by dual voltage is not used 90 percent of the time.

Heat Treating

C. F. Cone*: There has not been a very wide application of heavy powered furnaces to steel mills but we hope that this will gradually increase as it has in the automotive and enameling industries. When the electric furnace was first developed, these industries purchased very small equipments for special heat treating work. In using the small equipments they were able to determine that electric heat could be economically applied to their work. At the present time, the size of furnaces in these industries have materially increased and although 500 and 600 KW equipments are not the average, they are not at all unusual. There has been one furnace sold that has a capacity of over 3000 KW. In any case where temperature control is essential electric furnaces should be given serious consideration before any other type of equipment is purchased. There are a number of applications in the steel mills where electric furnaces could be applied economically. At the present time there are not any real large installations in steel mills but many of the companies are installing electric furnaces for miscellaneous heat treatment. We hope that by the use of these equipments it can be definitely determined that there is a wide application for electric furnaces.

D. M. Petty‡: Originally all of our heat treating people considered the electric furnace as something to be used where very accurate temperature control was desired and considered it more or less a luxury, whereas recent experience has shown where power has been available to the furnace at 1c per k.w., a ten-ton furnace for heat treatment of bar stock has shown a lower cost than a similar treating of some product in a furnace being fired with oil, which indicates to me and might be of interest to members in general, that the time has arrived in larger size furnaces with a power cost at 1c per k.w. hour on a strictly cost basis, that the electric furnace will compete with oil-fired furnace.

Bright Annealing

W. Trinks†: The committee might make a reference to a committee report which has been published by the German Iron & Steel Institute on the question of bright annealing of steel sheets and steel strips. That report has come out recently and is a very good one. It shows the progress made on the other side of the Atlantic in bringing inert gas into the furnace and having the sheets and strips go out with a silvery luster. The sheets can enter black with scale and they come out looking like silver. Perhaps some of our industries will find a reference to that report interesting. The report to which I refer and which was prepared by Mr. A. Pomp and Mr. Ewald Schreiber is as follows:

*George J. Hagan Co., Pittsburgh, Pa.

‡Supt. Elec. Dept., Bethlehem Steel Co., Bethlehem, Pa.

†Prof., Mech. Engineering, Carnegie Institute of Technology.

EXPERIENCES WITH ELECTRICAL BRIGHT ANNEALING FURNACES§

By A. POMP*

Bright annealing is a frequently used method of annealing which produces a perfectly clean and bright surface of the material.

One of the best known methods (Vitry's Bright Annealing Method) starts from the knowledge that the oxidizing of the material is not caused in the reducing atmosphere of the furnace, but during the cooling by the absorption of air after removing the heating pot from the furnace. Vitry, therefore allows cooling of the heating pot in iron coolers, in which lighting gas is introduced from below. Figure 1 shows the cooler, after Vitry.

The Liequer Machinen Fabrik developed a method shown in Fig. 2, in which after the annealing process the pot is put in a cooler, on the bottom of which a dry fuel is to be found. The heat of the pot with its charge, gassifies the fuel, and in this way the oxygen in the air is neutralized. The surplus of the gas is pressed in a gas tank. After leaving off gassification the gases in the cooler and in the heating pot become cooler and draw together (contract) so that the gas goes back from the tank to the cooler.

The most favorable method seems to be an electric method of bright annealing which was perfected for Heraeus Co., and manufactured by the Siemens Klinkbert Co. The furnace consists of a body of brickwork the inside surface of which bears the heating elements, protected against touching and destroying. The furnace body is inside of an airtight sleeve, filled during the process with a protecting atmosphere which keeps off the oxygen. Different types of furnaces have been developed for different materials and classes of material. Fig. 3 shows the bright annealing muffle furnace for 35-KW with lifted cap—generally used for the annealing of sheets. The heating element consists of one or more endless bands put into brick joints inside the furnace. As the protecting atmosphere not only protects the material to be annealed, but the heating element as well, the life of this element is very long. For this same reason it is not necessary to use chrome-nickel or other expensive alloys for it. It is sufficient to use common strip steel. The lower half of the muffle furnace shown in Fig. 3 consists of a platform, the edges of which form the oil pot. To charge the furnace: take off the head and after charging put it back in the oil cup. Fig. 4 shows the furnace ready for work.

For the inlet and outlet of the protecting gas the head and bottom have been provided with gas connections. To avoid explosions, nitrogen or carbonic acid must be blown through the furnace before starting, to push away the air; after that lighting gas, hydrogen or water must be passed. The connection for the electric current is of airtight construction. At different points of the sleeves pipes are welded in, through which the temperature can be watched; for the same purpose two or three thermo-couplers are put in, lying in the brick work, and in the middle of the charged material. The temperature of the sleeves

§Translated from the German by: M. E. Link, 421 Washington St., Steubenville, O.

*Dusseldorf, Germany.

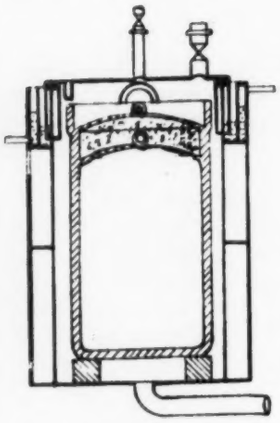

FIG. 1.

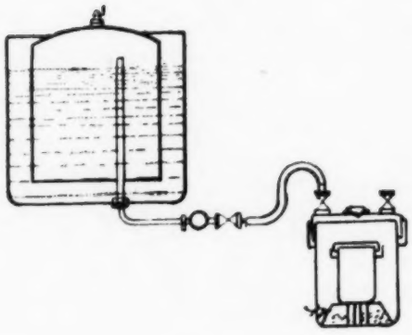

FIG. 2.

FIG. 3.

FIG. 4.

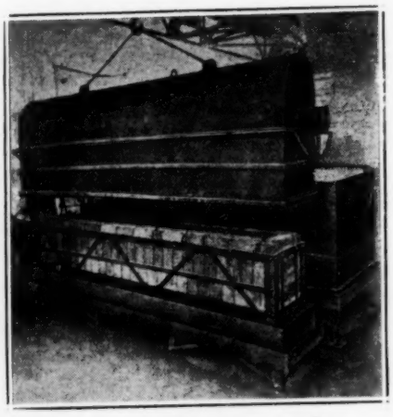

FIG. 5.

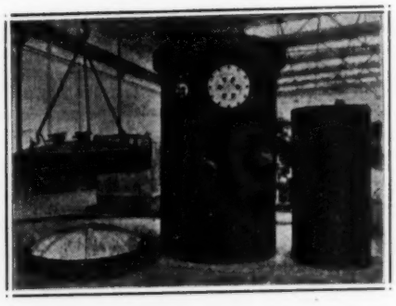

FIG. 6.

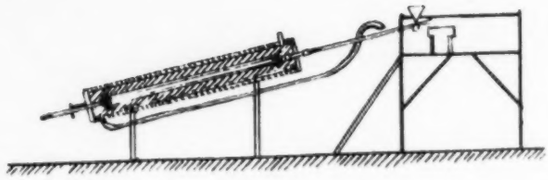

FIG. 9.

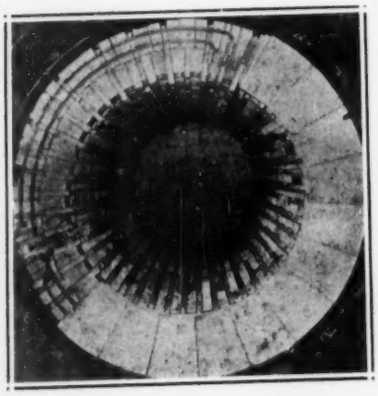

FIG. 7.

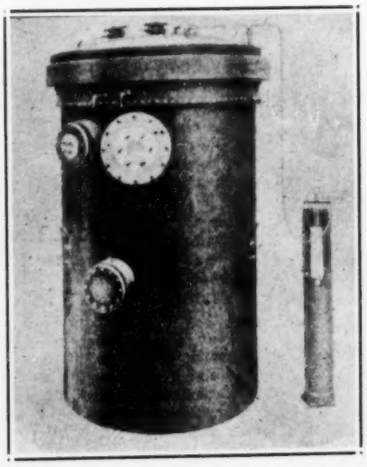

FIG. 8.

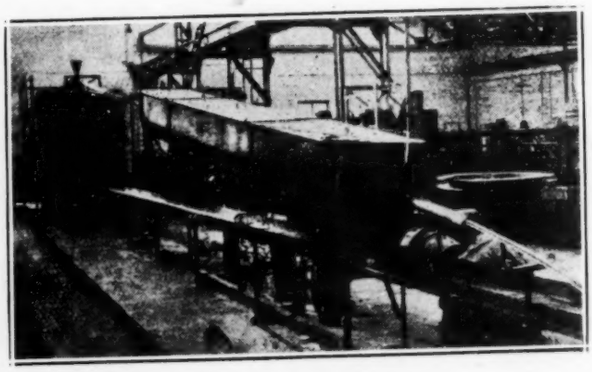

FIG. 10.

reaches not more than 250 to 300 deg. Fahr for furnace temperatures of 1475 to 1930-Fahr.

Bright Annealing

The furnaces work with every kind of electrical current, but a tension of 220-Volts is most commonly used. Within two to three hours the temperature is brought to 750-deg. Fahr., and within 3 to 4 hours more it can be brought to about 1475-deg. Fahr. Then it remains uniform. At the end of the desired annealing time the current is turned off and the furnace becomes cool within three to five days, according to the size of the furnace and the weight of the charged material. Now it may be discharged without danger of explosion.

Fig. 5 shows a trough bright annealing furnace, which is 9-ft. long, and required 40-Kw. This furnace is charged and discharged from the top.

Fig. 6 shows a shaft furnace, requiring 100-Kw, used for annealing wire and strips in ring form. The bottom part of the furnace lies mostly below the floor elevation and consists of a cylindrical body carrying an oil cup.

Fig. 7 shows the inside of the furnace, and the electric connection and heatlng strips.

Fig. 8 shows this shaft furnace ready for work.

In the following are related some of the experiences of different plants.

A tin mill uses for the annealing of thin sheets for deep drawing purposes a muffle furnace of about two-ton capacity, having an electrical consumption of 180 to 200-KWHours per ton. The heating time lasts twelve hours; cooling requires about two and one-half days, which is the unfavorable part of this process. Hydrogen is used as a protecting gas, and also helps reduce the oxidizing. Hydrogen consumption is rather high—about 540-cu.ft. per ton.

The advantage of this process is that the iron leaves the furnace with a bright surface, with no loss through oxidizing, and the cost of pickling is decreased.

A large shaft furnace of 20-ton capacity, and for the same purpose as given above, did not work well, in spite of the blowing through of large quantities of hydrogen the sheets were discharged black. This was probably due to the amount of vapor produced. Assuming this to be 1% for a 20-ton charge, would produce vapor amounting to about 140-lbs. of water. At a temperature of 400-deg. to 500-deg. Fahr. a small percentage of steam is sufficient to produce oxidization. Therefore it is absolutely necessary to get rid of the steam before the cooling period begins. To attain this result either a large quantity of hydrogen is required or cooling chambers must be built in at the proper points for condensation of the steam.

For bright annealing of strip steel another plant used a 2-ton shaft furnace, with a consumption of 320-Kw Hrs. per ton. Temperature runs from 1475 to 1500-deg. Fahr. Heating time 8¼-Hrs. Cooling time 4 to 5 days. Hydrogen consumed about 100-cu. ft. per ton. Electrical bright annealing is used in this case, not only for finish annealing, but also for intermediate annealings. These bright annealed strips are rolled without any pickling.

The bright annealing furnaces mentioned cannot be worked without interruption as the material can be discharged only after cooling of the furnace. The cost of electric current therefore is proportionately high, as the furnaces must be re-heated after each cooling period. This disadvantage is avoided by the electric bright annealing piping furnace. This furnace is especially suitable for annealing material of straight expansion, for instance: rods, pipes, etc.

Fig. 9 shows this type of furnace. The annealing chamber is represented by a pipe of round or square section, of steel or carbon iron, depending on the temperature desire for operation. This pipe is further extended by another of similar section, serving as a cooling zone.

This annealing pipe is surrounded by electric heating stripes, and put in an air-tight sleeve. The space between the pipe and the sleeve is filled with fireproof granulous material. Hydrogen is passed through both the annealing and cooling zones; it also passes through the space between the sleeve and the pipe, to protect the heating element and the outside of the pipe.

The material to be annealed is charged at the low end of the furnace, and passes through the preliminary heating zone, heating zone, and cooling zone, and is discharged after passing an air-tight sand enclosure.

Fig. 10 shows the bright annealing piping furnace, used for annealing of chrome-nickel rods. Furnace is 18-ft. long, 3-ft. inside dia., and requires 30-Kw. Temperature is continuous at about 1690 to 1750-Fahr. Consumption amounts to about 210 to 220-KWHrs. per ton, and 55-cu. ft. of Hydrogen per ton. For the annealing pipe a cast iron pipe is preferable to a steel pipe.

This same type of furnace is used for the annealing of steel pipes used in the manufacture of hollow needles. The furnace is 9-ft. long 3'-6" inside dia. working at a temperature of 1480-deg. Fahr. Furnace is turned on at 6-A.M. and turned off at 5-P.M. During the night the temperature drops to about 1100-deg. Fahr. Consumption is 70-Kw. Hr. per 24-Hrs. Daily output about ½-ton. The steady temperature guarantees a uniform material, which is important for this purpose. Since the introduction of annealing by electric means the number of annealings required has been reduced from 20 to 15.

From these descriptions the advantages of electric bright annealing furnaces are apparent. Construction of the furnace is simple and reliable. Large foundations, stacks, flues, coal and ash conveyors are unnecessary. Tending the furnace is a simple matter. Wear and tear on the annealing pot is practically negligible. Another important item is the security with which certain temperatures can be reached and maintained. In cases of intermediate annealing pickling is saved.

Except in the case of the continuous piping furnace, the long cooling period (during which the furnace is out of use) is unfavorable.

The economy of the method depends principally on the price of electric current.

TESTS WITH AN ELECTRICAL BRIGHT ANNEALING FURNACE

By EWALD SCHREIBER*

We have made tests with an electric heated bright annealing furnace, of the Heraeus Company. The furnace has an inside diameter of 3-ft.,

*Chief Engineer.

and an inside height of 6-ft., with oil seal and water cooling. The furnace is for 3-Phase current; it has an outside sheet cylinder and brick lining. The heating strips are of soft strip steel, laid within the brick joints.

Eight tests were made; the first and sixth could not be finished in consequence of troubles. The results of the other six tests are given in the attached tables.

For these tests soft strip steel in rings just from the rolling mill were used. The analysis of the steel is:

0.065% C 0.45 Mm. 0.05% S. 0.06% P

The size of the strips was 300 and 460 times 4-ft., and 180-ft. times 4-ft. 4-in., with a weight of 120-lbs. to 140-lbs. Electric consumption depended on the weight of the charge. Slow heat is first turned on, until a temperature of 840-deg. Fahr. is reached, and then turned to intense heating. For equalizing it is alternately turned on slowly and intensely, which is

No. of Test	"B"	KWH	KWH per Ton	Charged Weight	Time for			HEATING			EQUALIZING			B. T. U.		
					Heating Hours	Equalizing Hours	Total Hours	Brick	Outside	Inside	Brick	Outside	Inside	Heating	Equalizing	Total
2	4¼"	780	650	2,420	8	2	10	1,830	1,585	1,345	1,830	1,650	1,810	554	40	594
3	8¼"	1020	810	2,530	6⅔	7⅔	14⅓	1,740	1,380	930	1,740	1,560	1,365	500	180	580
4	8½"	1030	545	3,820	8½	6	14½	1,795	1,450	880	2,010	1,725	1,280	535	388	923
5	8½"	1290	670	3,820	8⅔	8⅓	17	1,740	1,600	1,150	1,740	1,690	1,470	432	104	536
7	4"	1280	1870	1,265	11	1½	12½	1,870	1,760	1,600	1,885	1,780	1,690	330	24	354
8	8½"	1490	765	4,940	13	5	18	1,920	1,650	1,200	1,920	1,650	1,430	860	64	924

NOTE: Test 2 and 3 with protecting basket and without outside isolation.
" 4 " " " " " with " "
" 5 without protecting basket and without isolation.
" 7 with cast steel " " " "
" 8 " " " " with outside isolation.

the reason for the rise and fall in the curves† (noted with I in Fig. 11—representing the temperature of the strips and the brick work.)

Curve II represents the temperature of the outside of the ring and Curve III the temperature of the inside.

All these tests show that a uniform annealing heat during the quoted times could not be obtained in a horizontal direction. After 18-hours the difference between the inside and outside rings amounted to 220-deg. Fahr. In consequence of this either the strips laying outside or those laying inside were annealed too much or too little.

A "protector basket" made of sheets did not work well; a basket of cast steel with rough surface worked better.

The passing of the hydrogen worked all right.

The sheets were really bright.

Geo. H. Schaeffer‡: We have been trying to accomplish that same thing for some time, but so far unsuccessfully. I also thank Mr. Petty for that knock-out blow for the oil furnace. If the electric furnace can be introduced into a tonnage mill, I think the chance for introducing it into a mill that is not a large mill is very much greater.

D. M. Petty§: This bar stock is heat treated and is high grade alloy steel, but in large quantites.

Geo. H. Schaeffer: Our orders generally don't run to those sizes; sometimes an order comes for a bar a foot long.

Roll Heaters

E. N. Calhoun*: The Freyn-Design Electric Roll Heater is a device for preheating, by means of electric heat, the rolls in sheet and tin mills. Prior to the advent of the first Freyn-Design Roll Heater it was common practice to bring the rolls up to operating temperature by rolling narrow iron and heavy gauges. Rather unsatisfactory attempts were also made by using steam, gas flame, or stack gases for preheating.

The roll heater comprises two frames each carrying two flexible cylindrical sectors. These frames are arranged to clamp around a pair of rolls, while the latter are in place in their housing. The cylindrical sectors carry the heating elements on their internal surfaces, the latter being fitted snugly against the rolls, by means of a simple take-up device. In this way the rolls are heated by conduction, the temperature of the heat source being only slightly higher than that of the roll surface. For this reason the surface of the rolls is not injured by high temperature such as is liable to result from the direct application of an open flame from gas or other fuel to the roll surface. A penetrating heating action results from the use of electric roll heaters, which action gives no marked drop in temperature at the surface of the chill.

A decided advantage of the electric preheating method is the ability to secure definite and correct heat distribution with the proper temperature differential between the middle and the end of the roll face so as to remove the cross and leave the mill just a trifle hollow for initial rolling. The temperature distribution is influenced by the relation of heater width to roll width and by the disposition of

†Curves and figures mentioned could not be secured at the time of printing this article.

(From Reports of Committees of the Society of German Iron Miners of Dec. 15th, 1925.

‡Elect. Engr., Carpenter Steel Co., Reading, Pa.

§Elec. Supt., Bethlehem Steel Co., Lehigh Plant, Bethlehem, Pa.

*Edwin L. Wiegand Co., Pittsburgh, Pa.

the resistor within the heating elements. This resistor distribution is not uniform, a different distribution being required for each heater width. The proper distribution for each heater has been determined entirely by experiment and observation over an extended period.

The power input to electric roll heaters depends upon the size of rolls and the consequent size of the heaters. For a 28-in., diameter x 30-in., face roll heater, suitable for use on rolls having a nominal diameter of 28-in., and a width from 36 to 40-in., the power required is 48 kw. A heating period of 8-hr., is ordinarily used hence the energy consumed is 384 kw. hr. This amount of power is sufficient to preheat the rolls so that production ordinarily obtained at midweek can be obtained at the start of the first turn. At 1c per kw. hr. this results in a total cost of power per set of rolls, of $3.84. It should be noted that the power consumed is off-peak power and therefore entitled to a low rate.

The life of an electric roll heater has not yet been determined. The first roll heaters installed four years ago are still in service. Present construction is much more rugged than initial designs. Given reasonable care, the maintenance cost is very small and depreciation is not excessive.

Electric preheating of rolls is a comparatively new development inasmuch as the first installation was made in the middle of 1923. Notwithstanding this fact, 182 Electric Roll Heaters have been sold during the succeeding four year period.

Hardening High Speed Steel

W. Scott*: I understand it is being done at Columbia Steel Co.

Jas. Farrington†: They tried it out at the Columbia Steel Co. and it was not successful, so they had to do away with it; whether only temporary or not, I do not know, but I understand it hasn't proven successful with them.

C. F. Cone: I do not have any definite information about the installation referred to as all my information is in a sense, hearsay. The first installation made in Elyria was made with the idea of bright annealing the strips by the use of a gas filled chamber. Evidently considerable difficulty was obtained in using gas to control the furnace atmosphere and this was finally abandoned. The electric furnace, however, was continued as an annealing furnace but not as a bright annealing furnace. It is our understanding that as far as the annealing was concerned, this equipment was very satisfactory. At Butler, they installed a continuous annealing furnace and used the Glowbar high temperature units. I understand that they have now taken these units out and that the equipment is gas-fired, the claim being made that the units were a continual source of trouble and the maintenance on the furnace was extremely high.

Geo. H. Schaffer: Perhaps Mr. Trinks will give us a brief description of the process.

W. Trinks: There were several interesting items: one is the sending of steel strips through the furnace which contains an explosive gas, but the furnace is open at the time. That gas may burn but not explode. They use clean producer gas and a strip run parallel through the furnace. That has been successful in several installations. It gives experience they had with closed multiple type of furnace into which they induced hydrogen and they found it difficult to have bright annealing, because hydrogen combines with oxygen of the scale and also water vapor. Of course, as you know, water vapor is not inert. Hot steel and water vapor gives scale by a well known chemical reaction; so they changed to drying the water vapor off and produced condensation. That is clearly set forth. It also gives complete cost data per ton of sheets.

F. H. Kittredge*: We have an electric heating problem on hand to raise the natural temperature of coke oven gas up to 1100 or 1200 degrees fahrenheit. We find it quite a problem to find a refractory for supporting the heating element which will stand up under these high temperatures without disintegrating. We have used the Cromel & Solar resistance wire for the heating elements with good success, we also have experimented with different voltages, both a.c. and d.c. We have had the temperature on these heating elements up to 1800 or 2,000 degrees fahrenheit without any ill effects to the wire but the supporting refractories for the heating coils break down under these temperatures. We are on the track of a new refractory which we believe will stand up under the heat conditions.

W. Trinks: What is the matter with the Electric Arc for this service?

F. H. Kittredge: It might work. Coke oven gas does not seem to explode under the method which we are boosting this temperature.

W. Trinks: What happened to coke oven gas at that temperature?

F. H. Kittredge: Nothing special out of the ordinary. The process under consideration is to boost the normal temperature of the gas which is in the neighborhood of 400 degrees fahrenheit up to 1100 or 1200 degrees fahrenheit and maintain it under a certain cycle of time.

W. Trinks: Does the gas break up and form lamp black?

F. H. Kittredge: I don't think it does.

Electric Heating of Hot Tops

D. M. Petty: The principal reason we did not get anything out of it was not because the idea did not work, but the apparent cost was going to be so much greater than where brick or some other hot top is used. We can apparently obtain about as good results from Brick Hot Tops as from electrically heated hot top so that it did not appear to be worth while carrying it any further under present conditions. We do not feel that the experiments we carried on were conclusive at all, because the apparatus was very temporary and merely tried out to see what could be done.

We have very different characteristics in steel than what Mr. Watson gave on nickel. In nickel,

*Westinghouse Elec. & Mfg. Co.

†Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.

*Electrical Engineer, Illinois Steel Co., Joliet, Ill.

partial consolidation of the ingot is desired before arc is applied. In steel ingot you may close up and arc weld the top, but the pipe will be under that section. To be successful at all, the arc must be applied immediately on the teeming of the ingot and it is a question in my mind, with anything but very high grade electric steel, as to whether it would be found humanly practical to apply the arc fast enough where 150 tons is poured at one time. It would be impossible to get enough arcs in a row to eliminate piping in all the ingot of a 150 ton heat.

Geo. H. Schaeffer: Would like you to tell us what size ingot you tried it on and what electrode you used, and how much power you put in.

D. M. Petty: We tried it on an ingot about 19" square at the top, and used 3" graphite electrode. How many amperes we had, we do not know, because we put in all the current the electrode would stand and, apparently, that was not enough. In my judgment you want somewhere about 2000 to 3000 amperes. But based on those experimental results, it will never be applicable to a tonnage mill. It may be an advantage in high speed tool steel ingots or high grade alloy ingots where the price of steel is high per pound.

R. S. Shoemaker‡: Is the practice being continued at International Nickel?

Geo. H. Schaeffer: My information is that they are still using it.

High Frequency Furnace Developments.

H. A. Winne§: I haven't been very closely in touch with this work of late, but one point has been brought out which it seems to me is of great importance and that is that in high frequency furnaces of only about 100 pounds capacity the overall power consumption compares favorably with that secured in arc furnaces of several tons capacity and of course the control of conditions affecting the metal is very much better in the high frequency furnace than can possibly be obtained in the commercial forms of arc furnaces.

D. M. Petty: How about cost of apparatus as compared with induction furnace?

H. A. Winne: I have never seen a direct comparison of costs of apparatus but I should say that the first cost of a high frequency furnace equipment would be considerably greater than that of a straight induction type furnace of equivalent melting capacity, and of course the induction furnace is considerably more expensive than the corresponding arc furnace.

Geo. H. Schaeffer: Measuring the power on the high tension side they can melt at the rate of 650 k.w hours according to Doctor Northrup.

I saw an English patent covering the heating of strips, putting electrodes several feet apart to heat up the strip. I do not know whether that has been tried by any of our members. They are trying it in England. The committee is interested in these developments.

J. V. Calhoun: 2000° F. is pretty close to the temperature limit of nichrome elements. I have recently been informed that a material has been produced which can be used as a resistor for temperatures up to 3000° F. It is now being tested out. In a short time it is probable that definite information will be available as to whether or not it is going to be any good.

G. Mills: In connection with Mr. Petty's thought, there are now in operation 15 car type furnaces running on electric steel, on charges of from 4,000 pounds up to 100,000 pounds of steel. In high grade alloy and tool steel, probably 40 or 50 percent of that steel now being produced is electrically annealed.

J. V. Calhoun: To melt zinc electrically is not an electrical problem, but a mechanical or chemical problem. The trouble experienced, and that which is preventing the melting of zinc electrically, is the lack of a metal for the crucible that will withstand the action of molten zinc. At the present time there seems to be no metal or alloy which will give long life in melting zinc, which means that when it gives out the heating element is very apt to be destroyed. We are all looking for the metal or material that can be used as a crucible for zinc melting.

To melt babbitt metals, a temperature of not over 1000° F. is required. This is relatively speaking, a low temperature. It has been previously mentioned this morning that electric heating simplified process work, due to the fact that by means of automatic control a very close and accurate control of temperature can be had. For this same reason, electrically heated, automatically controlled melting pots will melt babbitt at the correct and critical temperature, thereby giving longer life to bearings poured from babbitt so melted. Would suggest that electric heating be given just consideration for doing this supposedly common, everyday job.

S. S. Wales*: We will thank Mr. Schaeffer and the rest of the committee for this report of the year's progress in Electric Heating and place it on file for reference.

We have so far overlooked electric welding altogether, and I am going to ask Mr. Schaeffer, if he can include this branch which is being nothing but proper application of sufficient heat at a selected point, and not essentially electrical at all, except as to the method of transporting the required energy, and I think that might come under his committee. There is no more important subject today and you will find that great progress in the development of welding is being made, so I will ask Mr. Schaeffer, if he will devote part of his time to electric welding for the remainder of the year, until we have an opportunity to consider the advisability of a special committee for the subject.

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‡Supt. Maintenance, American Rolling Mills, Middletown, O.

§Engr., General Electric Co., Schenectady, N. Y.

*Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.

*Discussion: Special Bearings Committee Report**

By MEMBERSHIP

B. R. Shover†: Considerable interest has been excited in steel circles during the past few months by the so-called "stripsheets" which have been put on the market by the Columbia Steel Company. For many years a great deal of time and money has been expended in an endeavor to eliminate manual labor in the production of sheets, but without success. The Columbia Steel Company attacked this problem from the hot rolled strip angle, and their success in producing what might be termed either a wide strip or a long sheet, has been due largely to their use of the following three factors:

1. Although the largest plate mill in the world, rolling plates up to and including 204" in width, is a four high mill. it was only recently that its manufacturers conceived the idea of using a similar construction for the rolling of strip.

2. The perfection of adjustable speed D. C. motor drive.

3. The use of roller bearings on roll necks, and it is this last item which is to be discussed at this meeting.

Several times in the past, papers have been presented before this Association, dealing with the use of anti-friction bearings for motors, cranes, roller tables, etc., so that the use of this type of bearing is by no means a novelty to steel works engineers. However, their application to the rolls themselves is comparatively new and undoubtedly the papers to be presented today will be both interesting and instructive.

The first paper will be presented by Mr. C. J. Klein, Engineer of the United Engineering and Foundry Company, who will tell us something about the general requirements of bearings used in rolling mills.

Mr. Klein's paper has given an idea of the requirements which must be met to successfully apply roller bearings to roll necks. He speaks of the application of anti-friction bearings on roller tables, and many of those here present can remember the prophecy of failure which attended early applications in this line, but, as seems to be the invariable rule in engineering that whatever is economically right will, in the end, succeed. Roller bearings have now come to be the standard for a large majority of uses throughout the steel industry, and the use of any other type in the majority of cases would be considered almost as backward a step as would the replacement of a motor drive on a roll train by a steam engine. The undoubted saving which can be accomplished by the application of anti-friction bearings to roll necks is so great that any reasonable amount of money and time necessary to solve the problem would be warranted. A great deal has already been done in this line, in fact sufficient to prove that the solution is not far in the future, as you will probably also decide after listening to some of the other papers.

*Presented at Annual Convention, June 14th, 1927.

†Chairman, Special Bearings Committee (Consulting Engineer, Pittsburgh, Pa.)

D. M. Petty*: I would like to say a word about Mr. Cramer's paper first and the others later. I feel Mr. Cramer has been very brave to put forth these points on sleeve bearings, especially in view of the fact that so many of the designing and selling engineers of the anti-friction bearing companies are present. However, he may have considered that any good and faithful servant who has performed his duty for many, many years is at least entitled to a decent burial. So it occurred to me that Mr. Cramer's paper was in the nature of a funeral oration for sleeve bearings. It recalled to me my high school days when I was studying Caesar, or was it Shakespeare? At any rate, I am referring to Caesar's funeral oration by Mark Antony, wherein he said, "We come here not to praise Caesar, but to bury him."

The thoughts on sleeve bearings were well put. Sometimes we might overlook that an installation could be better made with sleeve bearings.

There is one point on which I would like to elaborate, it is in connection with the study of armature failures as indicated by the questionnaire put out several years ago. Prior to the advent of the inter-pole in general purpose motors, a good many of the older type motors were of the pedestal bearing type. One advantage of this type of bearing is that it is located a considerable distance from the armature and therefore the real serious trouble with sleeve bearings, that of oil getting into the windings did not come about until the inter-pole was first put on the market and the bearings were put in end frames instead of on pedestals. Engineers were trying to get as much horse power out of each pound of material as possible; therefore, they not only brought the bearings in close to the armature but frequently made them too small. This is what started the trouble with sleeve bearings and is also the real reason why the ball bearing is so rapidly replacing the sleeve bearing in general purpose motors. On all large size bearings, particularly pedestal bearings, practically no trouble is caused from oil getting into the windings. No further testimony is needed than those many old motors installed prior to 1900 that are still in service, in many cases with the original bearings and in a few cases with the original brushes still in service. These bearings are larger and the speeds slower than is the case with the modern motor.

Roller bearings for roll necks. I would like to issue one word of warning to the mill owner in this case. In view of the progress which is evidently being made in the application of roller bearings to roll necks, the situation today may be a little farther advanced than the application of ball bearings to general purpose motors when the special bearing committee was formed. The special job of that committee was not to promulgate a certain size of ball bearing among users of motors, but rather to avoid the danger of having one company select 200 series bearings, another 300, and still another 400.

*Supt. Elec. Dept., Lehigh Plant, Bethlehem Steel Co., Bethlehem, Pa.

The principal object was standardization and greatly to our surprise the object was rather easily attained, inasmuch as practically all motor builders have standardized on ball bearings having the outside and inside dimensions of the 300 series. This is all the Special Bearings Committee started out to accomplish. It occurs to me that some study along the line of standardization in as many parts as possible on roll necks should be conducted NOW before it is too late; before Timken, Hyatt, SKF and others puts out what they think has the world beat. If the designers of mill bearings will get together and flourish the big stick a little and say we want something that is 16" in diameter we want to use either SKF, Timken, Hyatt, Rollway or any other roller bearing we happen to have we don't want to use your particular bearing for that particular installation, there is no reason why anybody's bearing that is on the shelf should not fit on that roll neck.

I believe Roller Bearings will practically replace other types for Roll Necks but a great effort must be made to standardize this type of Bearing in order to keep down the cost.

B. R. Shover: Mr. Petty's remarks are very pertinent to the subject and it might be well for any of the manufacturers of rolling mill equipment or anti-friction bearings, and the other engineers here, to give some consideration to it; and as chairman of the Bearings Committee for this year, I promise to bring that to the attention of the Association to see if it is not possible to accomplish a standardization in this new art before it goes so far along that we will have a condition to overcome similar to what was accomplished by the former committee on anti-friction bearings on motors.

W. Trinks†: I would like to ask what provisions have been made to keep scale and water out of anti-friction bearings? Furthermore, I wish to say that nobody, so far as I know, has given any credit to the metallurgist. If it wouldn't have been for metallurgists, we wouldn't have anti-friction bearings for rolling mills. Not so many years ago, German engineers tried to put anti-friction bearings in rolling mills, but most of them failed because the science of metallurgy was not far enough advanced to produce strong enough rollers and strong enough races. So we should not forget to give credit to the metallurgist.

Fred Waldorf*: We use from three to five grooves 1/8" wide by about 3/16" deep to keep the grease in the bearing box, the bore of the seal is made 1/64" larger than the diameter of the roll neck. The box is filled with greases by means of a gun until the grease works out past the grooves.

On our 16" mill we tried out five grooves and found that three are always filled with grease and the remaining two with grit. On other installations we have seen felt rings used in addition to grease grooves, the felt being held in position by kuper rings which are bolted to the bearing boxes.

The felt rings are very effective for keeping water out of the boxes. We have found that where water gets into the boxes the bearings themselves will etch somewhat in time.

Where water is likely to get into a bearing box, a live base grease should be used. A soda base will form an emulsion with water, a thing that should not be allowed to occur.

When oil is used as a lubricant we call for around a dozen grooves in the seal, the seal itself being bored out slightly larger than the shaft.

So far as I know, everybody has been able to keep the grease in the bearings and the scale and dirt out.

As regards the credit that is due the metallurgists, I think that Prof. Trinks is right. No greater tribute can be paid the metallurgist who has done so much to make anti-friction bearings the success they are than to cite the wonderful records already established by the few installations so far tested out.

E. C. Gainsborg*: We accomplish this by means of a disc or shell, which we call a flinger; it is fastened directly to the shaft and rotates with it. Labyrinth type flinger has a lip that rides within a groove on the end cover, with a clearance of .01" to .03". This enclosure is now used on wet end of paper machines and proven to be effective; it keeps water, dirt and foreign matter from entering the housing and also serves to retain the lubricant within the bearing chamber. The design has resulted from numerous tests, with enclosures of various kinds.

C. J. Klein†: We use different kinds of seals, and with oil lubricants we find a piston ring seal satisfactory where the pressures are below 10 pounds.

When using grease under pressure and keeping the bearing filled up there is very little chance of scale or water working into the bearings. In this case small grooves are sufficient packing.

W. A. Petry‡: I would like to know from the different makers of anti-friction bearings if they have standardized a grease to be used or standardized oil. Where they designate oil to be used, what are they going to do on cold saw work when ice banks up around the saw?

Fred Waldorf: We have chemists who continually make a study of lubrication problems. They work with any firm that has lubrication trouble and work up a system whereby they can keep the machinery lubricated. Wherever we put in an installation we find we have to take a certain grease and try it out, and so far as I know we have not had any trouble that could not be corrected.

W. A. Petry: We have cold saws and we have had a large amount of trouble with ice around the bearings. This bearing was designed for oil.

W. Trinks: Get a lighter oil.

Fred Waldorf: I am sure that all of the members of the Association on whom I have called have shown a desire to cooperate with us and have already been of considerable assistance to us. We will always have problems to solve that we do not now forsee, and it is only through your working with us that we will be able to overcome your difficulties.

I happen to know of the trouble Mr. Petry is having and if we can be of any service to him we will be glad to have him call upon us.

†Prof., Mech. Engineering, Carnegie Institute of Technology.

*Timken Roller Bearing Co., Canton, Ohio.

*Engineer, SKF Industries, Inc., New York.

†United Engineering & Foundry Co., Pittsburgh, Pa.

‡American Rolling Mills Co., Middletown, Ohio.

Light oils have solved many problems, but whether or not they will solve his, I cannot now say.

S. R. Cox†: What is the effect of the spring in the rolls on the bearing?

Fred Waldorf: As far as our experience is concerned, we have not found that spring of the rolls has had any serious effect on the bearings.

B. R. Shover: Some manufacturers take care of the affect of roll deflection by using two or more races with short rollers and in another instance the rollers are so shaped as to form practically self-aligning bearings. The best test so far on anti-friction bearings for this purpose, is at the plant of the Rome Copper and Brass Company, where a four-high mill, in which the backing up rolls are equipped with roller bearings, has been in continuous operation for about two years, after which use the bearings are apparently in perfect condition. Too much stress, however, must not be laid on this installation, because the very character of the mill reduces roll spring to almost a negligible quantity.

A. J. Standing*: I made a couple of notes in connection with Mr. Waldorf's paper. I was amazed at the savings accomplished by the application of anti-friction bearing to the rolling mill at their own plant. In other words, the saving seemed high in regard to amount of power required to roll steel.

We have an 18" structural mill with a 1500 HP drive. Some of the sections such as 6" beams and channels are on the upper limit of motor power available. If we can possibly gain this 46% reduction by applying roller bearings to this structural mill, we could eliminate the transporfation cost on the large sections which we now have to transfer to another mill.

I am interested in anti-friction bearings. As far as new work is concerned I think that is the step to take. But I agree with Mr. Cramer that in a great many cases where we have such satisfactory operations with sleeve bearings, we would be wasting money to make radical changes, except in places where we really find we have high maintenance cost. Another point is the spare situation. A continuous mill is a high tonnage range proposition and one delay, due to an armature, involves considerable expense.

Can anti-friction bearings be handled as quickly by normal repairmen as the present sleeve bearings?

Fred Waldorf: It would seem to me the answer to the question would be in the design of the housing. There may be a little extra expense with spare bearings. They must keep spare armatures in the rack and bearing is thoroughly protected at all times.

R. H. DeMott‡: The mill motor manufacturers have adopted a so-called cartridge housing for anti-friction bearings. The bearings are mounted on the shaft in the cartridge housings and then filled with the proper amount of oil. If an armature failure occurs, the armature with bearings and housings is lifted out and a new armature with its bearings and housings merely dropped into the motor frame. The old armature can then be sent to the Electrical Shop for repairs where in certain cases it may not be necessary to remove the housing to expose the bearings. With this construction it is easy to make a quick change of armature. Another advantage is that one armature spare will take care of several motors.

As for carrying spare bearings for general purpose motors, where the cartridge housing is not used I do not see that any great difficulty should be experienced. The Association of Iron and Steel Electrical Engineers has, through its recommended standards, made possible the use of one bearing for servicing several sizes of motors, consequently only few spare bearings need be carried for a large number of motors. These spare bearings are packed at the factory in sealed containers which preclude the possibility of dirt entry. The sealed boxes can be kept on the shelf until such time as the bearings are required, not until then should the seal be broken. The slushing compound which is used on the bearing forms a very excellent lubricant and need not be washed off when the new bearings are installed in the motor.

B. R. Shover: It has been common practice to carry each spare armature with its bearings on it. If a little mill dust collects, it means only a minute's time to have it wiped off. If I understood the question correctly it was that in order to make quick changes you can't take time to pull the races and bearings off and fit on the other and put them back; so that for some six months it will have this anti-friction bearing on it and the oil and grease would become incrusted with dust, so that you would not dare to put it in.

J. D. Rowbotham*: It appears to me that it is entirely up to the fellow who is handling the bearings to keep them in shape. I do know that many plants have their armatures together with its ball or roller bearings, assembled and on the spare rack, ready for use and these fellows have none of the trouble suggested in the gentleman's remarks. It is up to every one of us to further the anti-friction bearing and get it to a point where we can all use it more economically than the sleeve bearing.

B. R. Shover: The question has been asked in regard to speed limit of roller bearings which do not use retainers.

F. H. Buhlman†: It is a matter of finding the relation between the pressure and speed of the roll. It is obvious, of course, without retainer the roller will be larger at higher speed, and this, of course, depends on the size of the bearings. We have had experiences of bearings, mill size, that would run 500 without retainer successfully.

J. H. VanCampen‡: Any bearings on roller necks so far on any mill application?

E. C. Gainsborg: Some on mills were installed in 1922 and they have been in continuous service. We haven't had any failures, although there have been roll neck failures.

A. M. McCutcheon§: I wish particularly to comment on Mr. Cramer's paper in regard to ball and

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†Rollway Bearings Co., Syracuse, N. Y.

‡Chief Engineer, E. W. Bliss Co., Salem, O.

§Chief Engr., Reliance Electric & Engineering Co., Cleveland, O.

roller bearings rather than on the other papers. I feel a great deal like the man who when he first saw a railroad engine. It was standing and he said to his wife, they can't start that thing. Finally it started and as it speeded up faster and faster, the old man got excited, turned to his wife again and said, by heck, now they can't stop that thing. When Mr. Cramer said I had started discussion on anti-friction bearings in the steel industry when I presented a paper before this Association in 1921, I asked myself was it a mistake. If you will look back at that paper, I think you will find that paper did not advocate anti-friction bearings, but advocated an investigation of anti-friction bearings in the steel industry. Even if we can show that motors with sleeve bearings are better than anti-friction bearings, I shall still be glad that the paper was presented; is it not true that the reason the sleeve bearing has been so much improved was the competition from anti-friction bearings. I think the paper was well worth while.

Mr. Cramer has touched exactly on what should be done. You should analyze your experiences. You have had a whole lot of experience. There is no question but that there are wonderful records on oil sleeve bearings; also on all bearings. So far as I personally recollect it, I was neither for the anti-friction bearing nor for sleeve bearing. I agree with Mr. Cramer there are conditions where the sleeve bearing is better and conditions where anti-friction bearings are better. But I advise you try to decide on type rather than application from the standpoint of manufacture. Do you want one type of mill motor on one application and one on another when they are the same size motor? I think all the evidence that all you men have should be carefully weighed. Set up a ledger; there will be some debits and some credits. Can you not, for the next year or two, enter up your debits and credits and judge the case? If you do I dare say that the Iron and Steel members will render a decision on the right type of motor bearings because their decision will record the facts gained by experience.

One great advantage in anti-friction bearings which was not touched on by Mr. Cramer is the use of anti-friction bearings on a.c. motors. I have always thought this a tremendous argument in their favor. We have made a great many anti-friction bearing motors. Even if I wished to I could not say we have experienced no difficulties. Perhaps one of our worst unforseen difficulties was the grease getting out of the bearings. You can force grease out of any anti-friction bearing housing by forcing too much in. Leakage has occurred at the machined surface where the gap meets the end bracket. I did not foresee that a machine fit against a machine fit with the cap entering the housing more than ¼" in length would permit grease leakage but I now know well that it does, because I have observed it. The answer was very simple; put a paper gasket on that machined surface; since we started this I have noted many motors that previously leaked grease through that fit that now do not leak at all. Sometimes you will not recognize where the leakage occurs. We thought the grease came out along the shaft until we instituted a search and much to our surprise the grease was leaking through the fit. With ordinary temperature leakage did not occur, but when the grease was heated leakage took place. Where you have high temperature installation, we find a grease called marfatt is the best high temperature grease. We found this out through co-operation with a steel mill. It is also pretty fair when temperature is low; better than many other greases.

Some time ago I had an opportunity to review European practices and I did find that anti-friction bearings are used by many European electrical manufacturers. We hear many strong arguments from anti-friction bearing people for the use of their bearings. Much depends on the point of view. I think you have the only point of view worth while, for you have to live with the equipment. You had a questionnaire before and got results. If you could start getting experiences reported to a committee, you will get many facts in favor of anti-friction bearings, also many facts in favor of oil bearings. Balance up the account and render a decision.

J. L. Brown*: I should like to add a few remarks to what Mr. McCutcheon said. I should like to support his remarks and remarks by Mr. Cramer in regard to collecting data on different kinds of bearings used in industrial motors which may be found in steel mills. As has been stated there is a broad range over which bearings are used and in some places the anti-friction bearing is best and in other places the sleeve bearing is best; in still other places, probably either one will work perfectly satisfactorily if given the attention it requires. If the users of bearings are going to decide what bearings are to be used in what types of motors, they should analyze the situation before listing on a numerical basis only, motors that have failed and motors that have not failed.

Of these interesting problems that have been presented in regard to roll necks, I know very little, but I know enough about bearings in general to judge that probably anti-friction bearings will prove to be very advantageous for this purpose.

We find that it takes much more skill to correctly apply a sleeve bearing than to apply an anti-friction bearing. That is because of the peculiar nature of sleeve bearings. In the anti-friction bearing the separating medium Mr. Cramer spoke about is always present whether the speed is low or high. In sleeve bearings when the motor is at rest with no oil as a separating medium between the journal and bearing due to its being squeezed out under the heavy load, the coefficient of friction may become as high as .4. When the shaft begins to rotate the load being large and the speed correspondingly low, the coefficient of friction will drop to about 1/10 of what it was to start; or .04. If the speed is increased and the ideal condition for the operation of these bearings is obtained, the coefficient of friction will drop again to 1/10 of what it was when the oil film was imperfectly established and will become .004. That is why the anti-friction type of bearing has a great advantage at starting and at very low speeds because its coefficient of friction is equally small in starting or running.

If you have a problem of roll speed where you can't establish the oil film in the plain bearing you should undoubtedly have an anti-friction bearing. However, in industrial motors, we find the condi-

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tions are fairly ideal for sleeve bearings when they operate continuously and the oil film is therefore well established. With any motor 10 to 50 h.p. at 1800 r.p.m., we may get a bearing loss of from one-half to 1% of the total motor input. If you use a ball bearing you will probably improve that, but a number of experiments I have conducted indicate that for roller bearings, and especially some types of roller bearings that don't eliminate friction to as great an extent as others, the friction loss is about the same as with sleeve bearings running at moderately high speeds. With some types of ball bearings, the friction becomes very small. However, if you fill the housing with grease, and I say, grease, because we found it the most universally satisfactory lubricant for anti-friction bearings, there is danger of putting in so much that you will increase the total friction to many times what the friction of the ball bearing itself is and lose the advantage otherwise gained. Also if you use felt enclosures pressing tightly against the shaft the friction of the felt will cause the total friction to be a great deal more than for sleeve bearings without felt wipers.

In making an analysis, I would suggest that you analyze your problems on the above basis, because if you do not have a proper basis for making an analysis, you will probably not arrive at an intelligent result.

I should like to make a remark in regard to the joke about the passing of the sleeve bearing: It has not departed from where I have been. It is still being manufactured in large quantities. The anti-friction bearing demand for industrial use has been growing rapidly and is still growing and **will** probably grow until it has covered the field which belongs to it and until the newness of the idea has worn off. Everybody who has used them **knows** the troubles encountered with sleeve bearings. We have found where a customer is favorable to anti-friction bearings, such troubles as are encountered in their use are passed over lightly whereas this is not true in the case of customers who are not particularly favorable to anti-friction bearings. Troubles do arise, and they complain about them, and I, as the one who is responsible for the mechanical design of the industrial motors in our company, have had a great deal of trouble with anti-friction bearings from one cause and another. Some difficulties we have been able to overcome and some have not yet been overcome. Another thing I should like to point out is if you contemplate using anti-friction bearings and you don't know much about them and aren't particularly favorable towards them, you must use great care in handling them and using them in order to secure satisfactory results.

You must lubricate these bearings occasionally. There are many greases not suitable for ball or roller bearings. The grease Mr. McCutcheon mentioned is a fine one for ball bearings from the freezing point of water possibly up to 150° C., but it seems too stiff to flow into roller bearings at moderate temperatures for the rollers continually squeeze the grease out of their path. Balls don't do this and on the contrary tend to wind the grease in. Marfak No. 3 just referred to is a good grease and there is another grade (No. 1) that is more suitable for lower temperatures, probably down to zero degrees Fahr. for ball bearings and for roller bearings at ordinary temperatures. These greases are soda base soap greases and are very stringy and sticky in consistency, but fluid through a wide temperature range. The No. 3 will readily take care of very high temperatures.

Going back to the care of these bearings: In the use of grease, it is usually necessary before adding new grease to take the housing apart to see if the old grease is still in good condition or not. That must be done carefully. Ball and roller bearings will not stand dirt. Mr. McCutcheon has mentioned the use of ball bearings for small air gap motors. We have had ball bearing motors where the internal radial looseness of the bearings after four months' service has been as much as 1/16" because dirt got into them and lapped down the balls in diameter sufficiently to result in this amount of looseness. You must keep them clean. You must not take them apart in a dirty factory. You must keep them covered with grease. I have had trouble in applying them on account of people giving them about the same care as sleeve bearings and they won't stand it. They must be kept free from corrosion. You must store them with more care than is usually accorded sleeve bearings. I have had some experience with both sleeve and anti-friction bearings and will just warn that, if you contemplate adopting anti-friction bearings, you plan to give them the care they must have.

I could make you a list of a dozen advantages for the sleeve type of bearing and a dozen for the ball or roller. In your analysis of the situation you must determine for each case or class of service which type offers the greatest net aggregate of advantages and then use that one.

J. S. Murray*: Mr. Cramer has contributed a very valuable paper to the literature of this association on the motor bearing situation. It is very significant in that it shows the good and the bad in both the anti-friction and the old reliable sleeve type bearings. It is only by frank discussions, such as this paper brings out, that we can form opinions on the merits of the two classes of bearings for electric motors.

My personal experience with motor bearings would lead me to concur in the statements made by Mr. Cramer. The real cause of this idea of anti-friction bearings for mill motors, in my opinion, was the fact that records show that a very large percentage of motor failures were caused by oil leaking out of the bearings and onto the motor winding. This oil together with dirt present in steel mills, no doubt, has caused excessive winding failures. This fact, however, was no fault of the sleeve bearing proper, but was due to the inadeuate design of the bearing housing which permitted the lubricant to escape and the gritty dirt to get in thus shortening the life of the bearing itself.

It is my opinion that it makes very little difference what the bearing metal is, whether it is good babbit, steel rollers or balls. If the housing is properly designed, with particular reference to holding the lubricant in and the dirt out, an exceptionally good bearing can be had.

We have experimented with both types of bearings during the last five years. We were probably one of the first to try out the so-called sealed sleeve

*Elec. Supt., Follansbee Bros. Co., Toronto, Ohio.

bearing on general purpose motors at the Toronto Plant in September, 1923. This original set of bearings are still in service and actually ran two years with the original oil. They were taken apart at the end of that time for inspection and found in perfect condition. Needless to say, the windings were gone dry and the bearings perfectly clean.

We have made about one hundred installations of this class of bearings, since that time and at a very small percentage of the original motor price. The results in every case are entirely satisfactory. Had we equipped these motors with anti-friction bearings, it would mean new motor shafts, and scrapping our stock of spare bearings. It was possible to use the latter by making a slight change in dowel pin hole.

Our experience with anti-friction bearings consists of installations in the past and at present on motors where no efforts were made to improve the present sleeve bearings in our motors by the manufacturers, thus justifying the expense of machining the housings and installing anti-friction bearings. Some of these installations have been successful while others were absolute failures. In fact, I know of one installation where sealed sleeve bearings replaced roller bearings entirely.

In conclusion, I believe that so far as I know there are no outstanding examples where the anti-friction bearings are superior to sleeve bearings, if given equal care in workmanship and materials; certainly the latter is cheaper to install and maintain. However, I hold no brief for the old style sleeve bearing. I believe that, when considering the purchase of new motors, the advantages offered by both ball bearings and **modern** sleeve bearings should be carefully considered and a choice made, based on the suitability of the type chosen for the particular application.

B. R. Shover: The remarks in regard to Anti-Friction versus Sleeve Type Bearings emphasize the reason for this session. Engineering has proven that there is no panacea for all ills and that practically all cases have to be studied separately, and require the use of the engineer's best judgment in solving the difficulties.

From long connection with this Association I am very much in favor of the suggestion which has been made, to have them proceed with the study of the question which has been before us today. In a large Society such as this, there will always be found certain prejudices, likes and dislikes, but I believe that as a body, this Association is as broad-minded and as open to the reasoning of others as is possible to find in any of the other professions, consequently it is to be hoped that the Executive Committee will see fit to act upon the suggestion, that the investigation and study of this subject be carried on by their Special Bearings Committee for at least another year.

It has been asked whether any failure of roll necks have been reported. There have been some failures as is always the case with a new device, but so far as has been reported these failures have not shown anything inherently wrong with the bearings themselves, nor have they discouraged the users; on the contrary they seem to have only spurred them on toward great efforts.

Items of Interest

The Delta-Star Electric Co., Chicago, Ill., have issued a 48 page publication devoted to high tension switching and protective equipment. This publication known as bulletin No. 32-B, has a picture thumb index to facilitate quick location of any desired equipment. Copy will be sent upon request.

We know our readers will be glad to learn that Mr. John F. Kelly, Business Manager of the Association and Editor of the Iron and Steel Engineer has been granted a two months leave of absence by the Board of Directors.

His long and faithful service to the Society and the strenuous duties imposed upon him by our recent Convention and Exposition taxed his strength to such an extent that a leave was granted so that he might regain his health. We know that his many friends will be glad to learn that he has been rewarded and all hope that he will returned with renewed energy.

The new water supply system at Tampa, Florida, was recently described and illustrated in an elaborate paper presented by Mr. Nicholas S. Hill, Jr., consulting engineer, before the New England Water Works Association. Thorough studies were made of sources of water supply, and available supplies were treated experimentally to determine the most suitable treatment process, including decolorizing, softening and recarbonization, as well as sedimentation and filtration. The paper has been reprinted and is being distributed by the De Laval Steam Turbine Co., Trenton, N. J., manufacturers of the geared turbine driven centrifugal pumps installed in the low head and high head pumping stations at Tampa.

The appointment of George St. J. Perrott, of North Dakota, as superintendent of the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, has been announced. Mr. Perrott succeeds Arno C. Fieldner, recently promoted to the post of Chief Engineer, Division of Experiment Stations. The Pittsburgh station is the largest of the eleven experiment stations of the Bureau of Mines, and is one of the notably large research institutions of the world. As superintendent, Mr. Perrott will direct the activities of approximately 200 scientific, technical and other employes in the conduct of various investigations dealing with safety in mining, the elimination of waste in the mining and metallurgical industries, and the technology of fuels, gases, and explosives.

Mr. Perrott has been a member of the staff of the Bureau of Mines for the past ten years, and has established a reputation as a research specialist in the technology of explosives and in the physical properties of coal and coke.

Mr. A. B. Holcomb, formerly District Manager for Clark Controller Company, has resigned to accept the position of District Manager for the D. B. Flower Manufacturing Company, manufacturers of Brush Holders.

Offices have been opened at 614 Empire Building, Pittsburgh, Pa.

The John Scott medal, given annually in recognition of "useful inventions for the use and benefit of mankind," has been awarded to D. D. Knowles, 28-year-old inventor of the Grid Glow Relay. Notice of the award, which carries a cash prize of $1,000 was given by Walter R. Russel, Acting Secretary. Presentation will be made at a later date.

Mr. Knowles perfected his invention in the research laboratories of the Westinghouse Electric & Manufacturing Company. His grid glow relay has been acclaimed as the most sensitive current-controlling device ever developed. The glow tube, which functions on a billionth of a watt, is set in operation by such tiny impulses as the mere approach of the human hand, a drop of water or the light of a match.

The fund for the award was established in 1816 by John Scott of Philadelphia.

Mr. E. A. Hurme, formerly connected with the Westinghouse Electric & Mfg. Company, now has charge of the Pittsburgh Office of The Clark Controller Company, succeeding Mr. A. B. Holcomb, resigned. The change took effect July 1st.

The Trumbull-Vanderpoel Electric Manufacturing Company of Bantam, Conn., manufacturers of the well known TV Safety Switches and Knife Switches have just brought out a very complete catalog on Safety Switches. It is really a most exhaustive manual covering the use and application of all forms of Safety Switches, of which they make a complete line.

Harnischfeger Corporation recently exported eleven of their latest model excavators to Cuba. These eleven machines are now working on the longest paved highway ever covered by a single contract.

The Central Cuban Highway will extend almost the full length of the island, passing through the provinces of Pinar Del Rio, Havana, Matanzas, Santa Clara, Camaguey and Santiago.

P&H machines are being used exclusively, and many dragline, shovel, clamshell and skimmer scoop attachments were purchased by the contractors with which to meet every requirement in connection with highway construction work.

It is estimated that $75,840,000 are involved in financing this extensive project. The finished paved highway will be more than 700 miles long. Carlos Migual De Cespedes, Secretary of Public Works, has pledged its completion in 1931.

The first electrically driven Grey mill in this country, and one of the largest mills of its kind in the world, was placed in operation at the Lackawanna plant of the Bethlehem Steel Company early in April. From the standpoint of total horsepower involved, it is one of the most highly powered mills in this country.

The mill consists of three units: (a) a 54-inch reversing blooming mill, which is one of the two largest reversing blooming mills in this country; (b) a 48-inch reversing roughing mill, and (c) a 48-inch reversing finishing mill. The rolling schedule covers a full range of Bethlehem beams, girders and columns.

The electric equipment for all the main drives was furnished by the General Electric Company. The 54-inch blooming mill is driven by a direct-current, reversing motor rated 7,000 horsepower continuously at 40/80 r.p.m. The direct current for this motor is derived from a fly-wheel motor-generator set consisting of a 5,000 horsepower, 375-r.p.m., induction motor, a 50-ton flywheel and two 3,000-kilowatt, 750-volt, direct-current generators operated in parallel.

The roughing mill has two driving motors. The main direct-current, reversing motor is rated 7,000 horsepower, 65/100 r.p.m. 750 volts. The supplementary motor, also reversing, is rated 1500 horsepower, 65/225 r.p.m. Direct current for these two motors is supplied by a flywheel motor-generator set consisting of a 5,000-horsepower, 375-r.p.m., induction motor, a 50-ton flywheel and three 3,000-kilowatt, direct-current generators. Two of these generators are operated in parallel, supplying power to the 7,000-horsepower motor, and the other generator furnishes power to the 1500-horsepower motor. The generators are duplicates, in the interests of standardization.

The finishing mill equipment is an exact duplicate of that installed for driving the roughing mill.

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fore, be a real help toward better operation of this type of machine.

The paper by Mr. O. K. Marti on "The Parallel Operation Of Mercury-Arc Rectifiers With Each Other, With Rotary Converters and With Motor Generators," deals with a piece of equipment that is coming into more general use, but about which comparatively little is known by the average Steel Mill Engineer. The Mercury-Arc Rectifier undoubtedly has "a place in the sun" and it is through such papers as the one by Mr. Marti that the possibilities and the limitations of this type of equipment can be fully understood.

The paper by Mr. Batt L. Spain on Centrifugal Compressors should be read carefully since most of us have always thought of the production of compressed air in terms of the reciprocating type of compressor. This paper will undoubtedly give a new viewpoint on the general subject of compression of gases.

The report of the Electric Heat committee which was published in the June issue dealt with a subject which is at least as old as our present knowledge of electricity and its manifestations. The easiest use out of electricity is to turn it into heat, but the proper application of this heat and the control necessary for electric heating equipment involve many problems that are far from easy of solution. The discussion of this report given in the present issue should be of great value whenever the question of heating electrically is considered.

The discussion of the Special Bearings Committee report which was published in the June issue, represents the ideas of Engineers who are meeting bearing problems every day. This discussion should be gone over carefully and kept in mind as a source of information on the question of Bearings.

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100-200-400
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600
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